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# Municipal Waste Combustion Multipollutant Study Emission Test Report. Maine Energy Recovery Company Refuse Derived Fuel Facility, Biddeford, Maine
## Volume 1. Summary of Results

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# Municipal Waste Combustion
# Multipollutant Study

## Emission Test Report

## Maine Energy Recovery Company
## Refuse Derived Fuel Facility
## Biddeford, Maine

## Volume I: Summary of Results

By

G. Scheil, S. Klamm, M. Whitacre, and J. Surman
Midwest Research Institute
Kansas City, Missouri 64110

and

W. Kelly
Radian Corporation
Research Triangle Park, North Carolina 27709

EPA Contracts 68-02-4463, W.A. 2 and
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Project Officer

James D. Kilgroe
U.S. Environmental Protection Agency
Air and Energy Engineering Research Laboratory
Research Triangle Park, North Carolina 27711

AIR AND ENERGY ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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16. ABSTRACT

The report gives results of an emission test of a new municipal solid waste combustor, in Biddeford, ME, that burns refuse-derived fuel and is equipped with a lime spray dryer fabric filter (SD/FF) emission control system. Control efficiency of the SD/FF emission control system was measured for polychlorinated dibenzodioxins (PCDD), polychlorinated dibenzofurans (PCDF), particulate matter (PM), cadmium (Cd), chromium (Cr), arsenic (As), lead (Pb), mercury (Hg), sulfur dioxide (SO2), and hydrogen chloride (HCl). Additional continuous monitoring was conducted for oxygen (O2), carbon dioxide (CO2), carbon monoxide (CO), nitrogen oxides (NOx), and total hydrocarbons (THC). Average emissions of total PCDD were 290 ng/dscm (uncontrolled) and 1.3 ng/dscm (controlled). Total PCDF emissions were 590 ng/dscm (uncontrolled) and 2.9 ng/dscm (controlled). Control efficiency was about 99.5% for both dioxins and furans. Particulate emissions averaged 7400 mg/dscm (uncontrolled) and 33 mg/dscm (controlled), for an average particulate control efficiency of 99.5%. Metals emissions varied from 500 micrograms/dscm for As and Hg to 30,000 micrograms/dscm for Pb (uncontrolled), and from 6 micrograms/dscm for As and Cr to 160 micrograms/dscm for Pb (controlled). Metals control efficiencies varied from 98.2% for Hg to 99.8% for Cr.

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| a. DESCRIPTORS | | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group | |
|---|---|---|---|---|
| Pollution | Fabrics | Pollution Control | 13B | 11E |
| Emission | Spray Drying | Stationary Sources | 14G | 07A, 13H |
| Refuse | Calcium Oxide | Municipal Waste Combustion | | 07B |
| Wastes | | | | |
| Combustion | | Refuse Derived Fuel | 21B | |
| Filters | | Fabric Filters | | |

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George Scheil, Senior Chemist, Field Measurements Section, of MRI's Environmental Chemistry Department, was the project leader. The project was conducted under the direction of Roy Neulicht, MRI's Program Manager for Incineration.

Process data were collected by Winton Kelly of Radian Corporation. HCl measurements were conducted by a team from Entropy Environmentalists, Inc., led by Ron Jernigan. A list of the participants in the project is given in Appendix N.

# ABSTRACT

This report describes the results of an emission test of a new municipal solid waste combustor which burns refuse-derived fuel and which is equipped with a lime spray dryer fabric filter (SD/FF) emission control system. The facility tested is operated by the Maine Energy Recovery Company and is located in Biddeford, Maine.

Control efficiency of the SD/FF emission control system was measured for polychlorinated dibenzodioxins (PCDD), polychlorinated dibenzofurans (PCDF), particulate matter (PM), cadmium (Cd), chromium (Cr), arsenic (As), lead (Pb), mercury (Hg), sulfur dioxide ($SO_2$), and hydrogen chloride (HCl). Additional continuous monitoring was conducted at various locations for oxygen ($O_2$), carbon dioxide ($CO_2$), carbon monoxide (CO), nitrogen oxides ($NO_x$), and total hydrocarbons (THC). Process samples were also collected and analyzed for metals and selected physical properties.

Average emissions of total PCDD were 290 ng/dscm ($0.1 \times 10^{-6}$ gr/dscf) (uncontrolled) and 1.3 ng/dscm ($5.7 \times 10^{-10}$ gr/dscf) (controlled). Total PCDF emissions were 590 ng/dscm ($0.3 \times 10^{-6}$ gr/dscf) (uncontrolled) and 2.9 ng/dscm ($1.3 \times 10^{-9}$ gr/dscf) (controlled). The control efficiency was about 99.5% for both dioxins and furans. All of the above results are corrected to 12% $CO_2$. The 17 specific PCDD/PCDF isomers, as well as the tetra through octa chlorinated total congeners, showed no significant change in distribution across the control device.

Uncontrolled particulate emissions averaged 7,400 mg/dscm (3.23 gr/dscf), and controlled particulates averaged 33 mg/dscm (0.01 gr/dscf) (corrected to 12% $CO_2$) for an average particulate control efficiency of 99.5%.

Metals emissions (uncontrolled) varied from 500 µg/dscm for arsenic and mercury to 30,000 µg/dscm for lead. Controlled metals emissions varied from 6 µg/dscm for arsenic and chromium to 160 µg/dscm for lead. Metals control efficiencies varied from 98.2% for mercury to 99.8% for chromium. The process ash sample results were in general agreement with the concentrations measured in the stack samples.

The continuous monitoring results and process data logging indicated that the combustion process was never under optimum operating conditions. There were frequent problems with feeder conveyors during all three test runs. CO concentrations averaged 70 ppm with some short duration excursions above 200 ppm.

The automatic SD/FF control system was not operating during these tests. During the first test, the stoichiometric lime-to-HCl + $SO_2$ ratio was 1.7, which resulted in an $SO_2$ removal efficiency of 66% and an HCl removal efficiency of 98%. During the early stages of the second test, the lime feed rate was doubled to give a stoichiometric ratio of 3.4. During the third test the stoichiometric ratio was 3.9 and removal efficiencies were improved to 90% for $SO_2$ and 99.4% for HCl.

This report was submitted in fulfillment of Contract 68-02-4463, Work Assignment No. 2 and Contract 68-02-4395, Work Assignment No. 27 by Midwest Research Institute under the sponsorship of the U.S. Environmental Protection Agency. This report covers tests performed during the period from December 8 to 12, 1987. Project work was completed as of May 1, 1988.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AA | Atomic absorption |
| AEERL | Air and Energy Engineering Research Laboratory |
| Btu | British thermal unit |
| CDPE | Chlorinated diphenyl ethers |
| CEM | Continuous emission monitor |
| CVAAS | Cold vapor atomic absorption spectroscopy |
| DDPE | Decachlorinated diphenyl ethers |
| dscf | Dry standard cubic foot |
| dscm | Dry standard cubic meter |
| EICP | Extracted ion current profile |
| EPA | Environmental Protection Agency |
| ESED | Emission Standards and Engineering Division |
| FD | Forced draft |
| FSCC | Fused silica capillary column |
| ft | Foot |
| GC/MS | Gas chromatography/mass spectroscopy |
| GFAAS | Graphite furnace atomic absorption spectroscopy |
| gpm | Gallon per minute |
| h | Hour |
| HpCDD/HpCDF | Heptachlorinated dibenzodioxin/furan |
| HRGC | High resolution gas chromatography |
| HxCDD/HxCDF | Hexachlorinated dibenzodioxin/furan |
| ICAP | Inductively coupled argon plasma |
| ID | Induced draft |
| in. | Inch |
| kg | Kilogram |
| $m^3$ | Cubic meter |
| MERC | Maine Energy Recovery Company |
| mg | Milligram |
| MM5 | Modified Method 5 sampling train |
| MRI | Midwest Research Institute |
| MS-SIM | Mass spectrosocpy-selected ion monitoring |
| MSW | Municipal solid waste |
| MW | Megawatt |
| MWC | Municipal waste combustor |
| NDIR | Nondispersive infrared |
| NDPE | Nonachlorinated diphenyl ether |
| ng | Nanogram |
| OCDD/OCDF | Octachlorinated dibenzodioxin/furan |
| PAS | Performance audit sample |
| PCDD/PCDF | Polychlorinated dibenzodioxin/furan |
| PeCDD/PeCDF | Pentachlorinated dibenzodioxin/furan |
| PM | Particulate matter |

# LIST OF ABBREVIATIONS (Continued)

| | |
|---|---|
| ppm | Parts per million |
| QAC | Quality Assurance Coordinator |
| QAP | Quality Assurance Plan |
| QA/QC | Quality assurance/quality control |
| RDF | Refuse-derived fuel |
| RPD | Relative percent difference |
| RRF | Relative response factor |
| SD/FF | Spray dryer/fabric filter |
| TCDD/TCDF | Tetrachlorinated dibenzodioxins/furans |
| THC | Total hydrocarbon |
| VOC | Volatile organic compound |

## SECTION 1.0

## INTRODUCTION

As part of the U.S. Environmental Protection Agency's (EPA) effort to develop and support regulations for municipal waste combustors under Section 111 of the Clean Air Act, EPA is sponsoring test projects at several new municipal waste combustor (MWC) facilities. These test projects include measurements to determine the emission levels of criteria pollutants, acid gases, heavy metals, and semivolatile organic compounds as well as the collection efficiencies of associated emission control systems.

Prior to EPA's decision to develop regulations for MWCs, Midwest Research Institute (MRI), under contract to EPA, compiled the available data base for the pollutants of interest (i.e., criteria pollutants, acid gases, metals, and semivolatile organic compounds).[1] Review of the emission data base was performed to determine the information gaps regarding achievable emission levels. Virtually no information was available for the pollutants of interest from new MWC facilities that fired refuse-derived fuel (RDF). The Maine Energy Recovery Company (MERC) located in Biddeford, Maine, was identified as the first new RDF-firing MWC with wet-dry (spray dryer) scrubbing and a high efficiency particulate collector to come on-line in the United States in the 1980s. To take advantage of the first opportunity to fill this information gap, EPA made a cooperative arrangement with KTI Holdings, Inc. (the owner/operator of MERC) to conduct emission measurements for the pollutants of interest. This report describes the details of the measurement procedures and the results of the MERC Test Project.

### 1.1 PROCESS DESCRIPTION

The Maine Energy Recovery Company (MERC) RDF power plant is located in Biddeford, Maine (see Figure 1-1). The plant is currently operating at a capacity of 454 Mg/d (500 tons/day) of municipal waste and wood chips.* The wood chips, and to a lesser extent, fuel oil and natural gas, are supplements to accommodate fluctuations in refuse volume and energy content of the RDF. There are two combustors each consisting of a Detroit Stoker RDF spreader stoker and a Babcock & Wilcox controlled combustion zone boiler. Each unit is rated at 158,200 MJ/h (150 x $10^6$ Btu/h). In combination they can provide steam for electric power generation up to 22 MW. For this test series, the plant was fired with RDF only.

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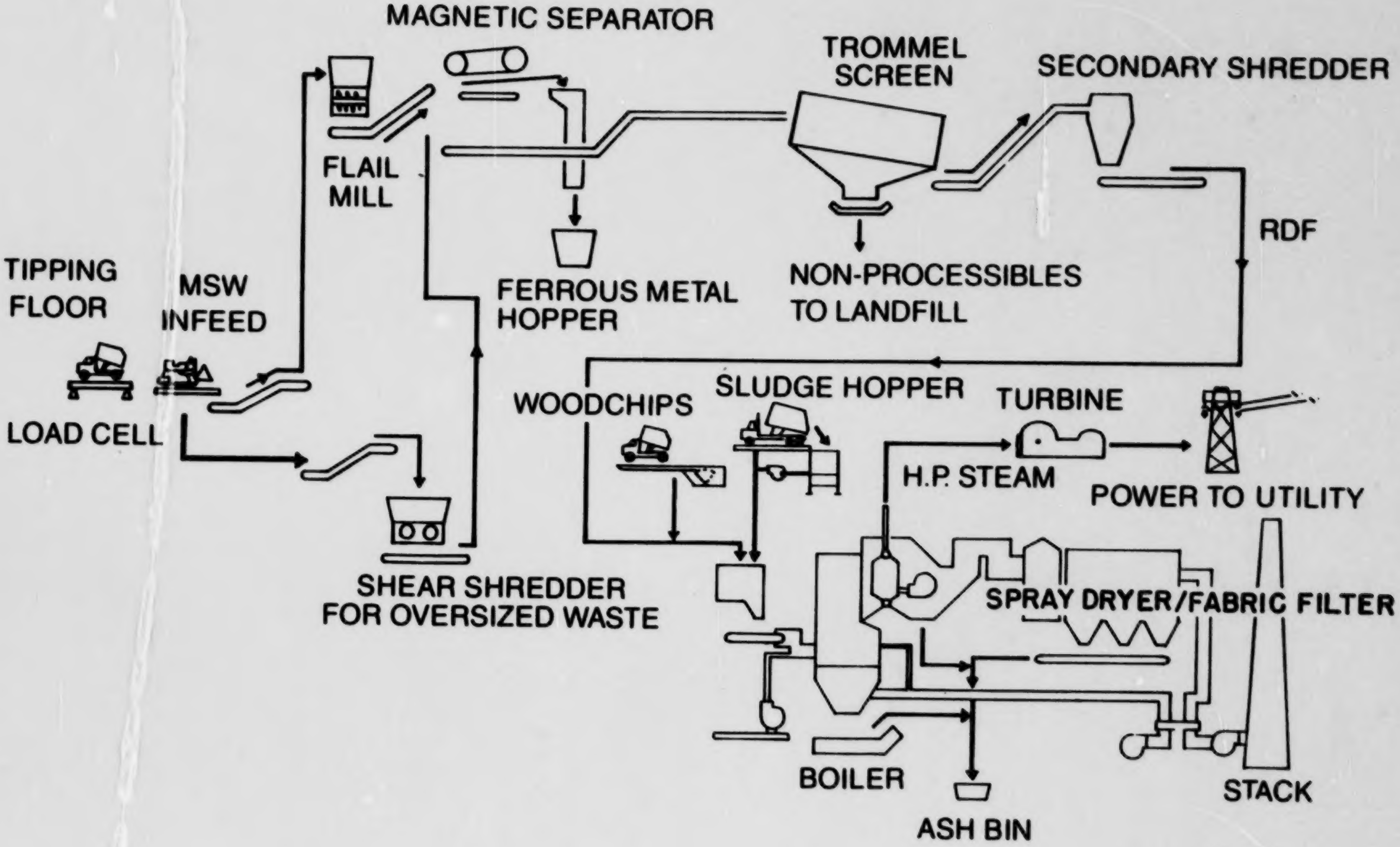
* A table for conversion of English units to Standard International (SI) units is provided at the end of this volume.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FERROUS METAL HOPPER
NON-PROCESSIBLES TO LANDFILL
RDF
LOAD CELL
WOODCHIPS
SLUDGE HOPPER
TURBINE
H.P. STEAM
POWER TO UTILITY
SHEAR SHREDDER FOR OVERSIZED WASTE
SPRAY DRYER/FABRIC FILTER
BOILER
ASH BIN
STACK

Figure 1-1. MERC Waste-to-Energy Process (Adapted From KTI Holding Co. Brochure).

Municipal solid waste (MSW) is received in packer trucks and transfer trailers and is off-loaded onto the floor of the tipping floor building. Noncombustibles and potentially explosive or hazardous items are sorted and removed by visual inspection and bucket loader. The MSW is processed using a flail mill, a magnetic separator, a trommel screen, and a secondary shredder. The resultant RDF has a nominal 10-cm (4.0-in.) top size. The plant has the capability of burning small quantities of sewage sludge, but it was not fired during the tests.

Dust control within the processing building is achieved through two separate control systems. One system serves the tipping/processing area, while the other serves the conveyors in the boiler building and RDF reclaim area. Each system contains a baghouse, fan dust hoods, and dust collection ducts at key conveyor and transfer processing points. Dust-laden air is drawn through one of two pulsed jet baghouses which exhaust in the vicinity of the boiler forced draft fan intake. The baghouse exhaust thus becomes incorporated into the combustion air for the boilers. Dust contained by the baghouse is returned to and becomes a part of RDF fuel.

Each boiler is a balanced draft (employing both forced and induced draft fans) water wall power boiler with a super heater, economizer, and air preheater. A traveling grate stoker is located at the bottom of the furnace. Fuel from metered feeders is admitted above the grate at the front of the boiler. A single auxiliary burner capable of firing natural gas or No. 2 fuel oil is located on the right furnace sidewall directly above the primary fuel combustion zone. It is used for startup, shutdown, and for periods where load stabilization is required. Medium-pressure superheated steam is delivered from the boilers to a steam turbine which supplies power to an electric generator.

Combustion air for the solid fuels is introduced into the furnace as undergrate and overfire air. The boiler configuration and the location of overfire air ports are designed to promote mixing and complete combustion of organic material injected into the boiler as fuel.

A transmissometer in conjunction with oxygen ($O_2$) and carbon monoxide (CO) monitor is used to optimize combustion efficiency and to control organic compounds and CO. These monitors are equipped with continuous recording devices.

Combustion gases from each boiler enter a spray dry adsorber followed by a fabric filter. Exhaust from each baghouse vents through a common 74-m (244-ft) stack. The spray dryer is a reaction vessel where a slurry of slaked lime is sprayed into the flue gas which contains particulate matter, acid gases, and other pollutants in gaseous and aerosol form. The slurry water is evaporated by the flue gas heat, and the acid gases react with the slaked lime (calcium hydroxide). Particulates, post-reaction compounds, and excess sorbent serve as nucleation points for adsorption and agglomeration of volatile metals and semivolatile organics. Some of the solids settle in the reaction vessel and are removed. A baghouse then collects the remaining particulate from the gas stream. The excess lime in the bag filter cake provides a second stage reaction site for further acid gas removal.

The ash system removes ash from the grate discharge, generating bank hopper, air heater hopper, mechanical dust collector hopper, spray dryer, and baghouse modules.

The boiler bottom ash discharges into a quench pit with a water seal and is removed by a drag chain up an inclined dewatering conveyor. All of the hopper discharges are through rotary seal valves. This ensures a positive seal and prevents boiler gases from entering the ash conveyors and air from entering the hoppers and boilers.

The ash from the baghouse modules discharges into six identical drag/screw conveyors. Each set of these drag/screw conveyors then discharges into one of two identical drag chain collecting conveyors.

The spray dryer and mechanical dust collector each discharge solids directly onto the collecting drag chain conveyor. The generating hopper and air heater hopper discharge ash onto the transverse drag conveyor, and it is then deposited on the collecting conveyors into one of two identical ash conditioning screw conveyors per system. The third screw conveyor in each system is the ash conditioner. The water flow rate and screw speed are automatically varied depending on the ash level within the conveyor. The ash conditioners discharge onto the dewatering section of the bottom ash drag conveyor. It is at this point that the fly and bottom ash streams mix. The bottom ash from the stoker discharges into one of two submerged ash conveyors. The combined ash streams are then dumped into a specially designed trailer for removal from the site to a landfill.

## 1.2 MEASUREMENT PROGRAM

A total of three tests were conducted at the MERC facility during the period of December 9 to 12, 1987.

The test matrix for this program is summarized in Table 1-1. MRI conducted all sampling activities for the program, with the exception of the HCl continuous emission monitoring system (CEM), which was operated by Entropy Environmentalists Inc.[2] Radian Corporation provided support in monitoring the process conditions during the test.

The basic sampling program included:

1. Sampling for polychlorinated dibenzodioxins (PCDD), polychlorinated dibenzofurans (PCDF), particulate matter (PM), cadmium (Cd), chromium (Cr), arsenic (As), lead (Pb), mercury (Hg), oxygen ($O_2$), and carbon dioxide ($CO_2$) at the spray dryer inlet.

2. Continuous emission monitoring of $O_2$, CO, $CO_2$, sulfur dioxide ($SO_2$), hydrogen chloride (HCl), and total hydrocarbons (THC) at the spray dryer inlet.

3. Continuous monitoring of HCl, $O_2$, and $CO_2$ at the fabric filter inlet.

TABLE 1-1. SUMMARY OF SAMPLING AND ANALYSIS PARAMETERS AND METHODS

| Sampling location$^{a}$ | Sample type | Sampling frequency/duration for each run | Sampling method | Sample size | Analytical parameters | Preparation method$^{b}$ | Analytical method$^{b}$ |
|---|---|---|---|---|---|---|---|
| 1-Spray dryer inlet | Combustion gas | Continuous 4 h | MM5-P/M$^{c}$ | $\geq$ 120 ft$^{3}$ | Particulate<br>Metals$^{d}$ | Desiccation<br>Acid digestion | Gravimetric (EPA M5)<br>ICAP/AAS$^{e}$ |
| | | | MM5-SVO$^{f}$ | $\geq$ 140 ft$^{3}$ | PCDD/PCDF$^{g}$ | Solvent extraction | HRGC/MS$^{h}$ |
| | | | M3 | ~ 30 L | $CO_2$, $O_2$ | N/A | Orsat |
| | | | CEMS (MRI) | N/A | $CO_2$, CO<br>$O_2$<br>$SO_2$<br>THC | Gas conditioning | NDIR analyzer<br>Paramagnetic<br>Electrochemical<br>Heated FID (Beckman 402) |
| | | | CEMS (Entropy)$^{i}$ | | HCl | | IR gas filter correlation |
| 2-Spray dryer outlet | Combustion gas | Continuous 4 h | CEMS (MRI) | N/A | $CO_2$<br>$O_2$ | Gas conditioning | NDIR analyzer<br>Polarographic analyzer |
| | | | CEMS (Entropy)$^{i}$ | | HCl | | Specific ion electrode |
| 3-Fabric filter outlet | Combustion gas | Continuous 4 h | MM5-P/M$^{c}$ | $\geq$ 120 ft$^{3}$ | Particulate<br>Metals$^{d}$ | Desiccation<br>Acid digestion | Gravimetric (EPA M5)<br>ICAP/AAS$^{e}$ |
| | | | MM5-SVO$^{f}$ | $\geq$ 140 ft$^{3}$ | PCDD/PCDF$^{g}$ | Solvent extraction | HRGC/MS$^{h}$ |
| | | | M3 | ~ 30 L | $CO_2$, $O_2$ | N/A | Orsat |
| | | | CEMS (MRI) | N/A | $CO_2$<br>$O_2$<br>$NO_x$<br>$SO_2$ | N/A | NDIR analyzer<br>Polarographic analyzer<br>Chemiluminescence<br>Electrochemical |
| | | | CEMS (Entropy)$^{i}$ | | HCl | | IR gas filter correlation |
| RDF | | Run 1--one shovelful per grab. Three grabs total.<br>Runs 2 and 3--19 L pailfuls per grab from the ram feed. Three grabs per run. | | Fiber drum | | N/A | Archived |

(continued)

TABLE 1-1 (continued)

| Sampling location[a] | Sample type | Sampling frequency/duration for each run | Sampling method | Sample size | Analytical parameters | Preparation method[b] | Analytical method[b] |
|---|---|---|---|---|---|---|---|
| A-Cyclone ash discharge | Fly ash | Two grab samples every 30 min composited into two separate samples each run | Scoop (S007) | 1 kg | Metals[d]<br>% Combustibles<br>% Carbon | Acid digestion<br>N/A<br>N/A | ICAP/AAS[e]<br>ASTM E830<br>ASTM E777 |
| B-Fabric filter (baghouse) | Fly ash/spray dryer residue | One grab sample every 60 min. composited and split into four jars for each run. | Scoop (S007) | 1 kg | Metals[d]<br>% Combustibles<br>% Carbon<br>Resistivity<br>K factor | Acid digestion<br>N/A<br>N/A<br>N/A<br>N/A | ICAP/AAS[e]<br>ASTM E830<br>ASTM E777<br>IEEE 548-1984<br>N/A |
| C-Bottom ash discharge | Bottom ash | Two grab samples every 30 min composited into two separate samples each run | Scoop (S007) | 1 kg | Metals[d]<br>% Combustibles<br>% Carbon | Acid digestion<br>N/A<br>N/A | ICAP/AAS[e]<br>ASTM E830<br>ASTM E777 |
| D-Spray dryer inlet | Lime slurry | One grab sample every hour composited into one sample for entire test | Tap (S004) | 100 mL per grab | Metals[d] | Acid digestion | ICAP/AAS[e] |

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[a] Numbers or letters refer to Figure 1-2.

[b] Sample preparation and analytical methods are described in detail in the Appendix of the Project Quality Assurance Work Plan referencing SW-846 methods and draft metals protocols.

[c] Modified Method 5 train for particulates and metals.

[d] Target metals are cadmium, total chromium, mercury, lead, and arsenic.

[e] Inductively coupled argon plasma atomic emission spectroscopy and graphite furnace atomic absorption spectrometry.

[f] Modified Method 5 train for semivolatile organics.

[g] PCDD/PCDF includes all tetra through octa dioxins and furans, all 2,3,7,8-substituted isomers, and to the extent possible, 1,2,3,4,8,-PeCDF and 1,2,3,4,7,9-HxCDF.

[h] High resolution gas chromatography/mass spectroscopy.

[i] Entropy Environmentalists Inc., is conducting the HCl monitoring under separate contract.

4. Sampling for PCDD, PCDF, PM, Cd, Cr, As, Pb, Hg, $O_2$, and $CO_2$ at the fabric filter outlet.

5. Continuous monitoring of HCl, $CO_2$, $SO_2$, $NO_x$, and $O_2$ at the fabric filter outlet.

The specific PCDD/PCDF congeners of interest requested by EPA are listed in Table 1-2.

In addition to the combustion gas sampling, RDF, ash, and lime slurry samples were collected for analysis. Figure 1-2 identifies the sampling locations. All sampling for this project was conducted on the "A" side combustor/boiler.

Operating parameters for the RDF combustion process were monitored by a computer-controlled system. Seventy-two process parameters were selected based on previous testing performed by Babcock and Wilcox, the combustor manufacturer. Data were logged using a portable computer linked to a printer port of the facility's computer-controlled system. The selected operating parameters were scanned at intervals of 4 min, with data being transferred to the portable computer and stored in Lotus 1-2-3™ files. The 4-min readings were averaged for each test period. Intervals of 15 min or longer during which flue gas sampling was suspended were not included in the test period averages.

## 1.3 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

An extensive QA/QC program was developed for this project. Audit samples for metals and dioxin/furans were provided by both EPA and the MRI quality assurance coordinator. Criteria for calibration accuracy and drift were developed for both sampling equipment and the CEMs, as well as for the laboratory analyses. Selected samples were analyzed in duplicate. An external audit was also conducted by Research Triangle Institute (RTI) in January 1988. The results of the QA/QC checks are discussed in Section 6.0.

## 1.4 DESCRIPTION OF REPORT SECTIONS

This report is presented in three volumes. Volume I includes the Summary of Results (Section 2.0), Process Description and Operation (Section 3.0), Sampling Locations (Section 4.0), Sampling and Analytical Procedures (Section 5.0), Quality Assurance/Quality Control (Section 6.0), and References (Section 7.0).

Volumes II and III contain the Appendices to this report with copies of the field and laboratory data. Volume II includes sample calculations, process data, field data sheets for the dioxin/furan and metals/particulate trains, process sampling data sheets, and CEM data. Volume III contains laboratory analysis for dioxin/furans and metals/particulates, miscellaneous laboratory analyses, sampling train calibration data, field test logs, QA information, sampling and analysis protocols, and the list of participants.

TABLE 1-2. PCDD/PCDF ANALYTES

Isomer

Dioxins

2,3,7,8-TCDD
Total TCDD
1,2,3,7,8-PeCDD
Total PeCDD
1,2,3,4,7,8-HxCDD
1,2,3,6,7,8-HxCDD
1,2,3,7,8,9-HxCDD
Total HxCDD
1,2,3,4,6,7,8-HpCDD
Total HpCDD
Total OCDD

Furans

2,3,7,8-TCDF
Total TCDF
1,2,3,4,8-PeCDF
1,2,3,7,8-PeCDF
2,3,4,7,8-PeCDF
Total PeCDF
1,2,3,4,7,8-HxCDF
1,2,3,6,7,8-HxCDF
1,2,3,4,7,9-HxCDF
2,3,4,6,7,8-HxCDF
1,2,3,7,8,9-HxCDF
Total HxCDF
1,2,3,4,6,7,8-HpCDF
1,2,3,4,7,8,9-HpCDF
Total HpCDF
Total OCDF

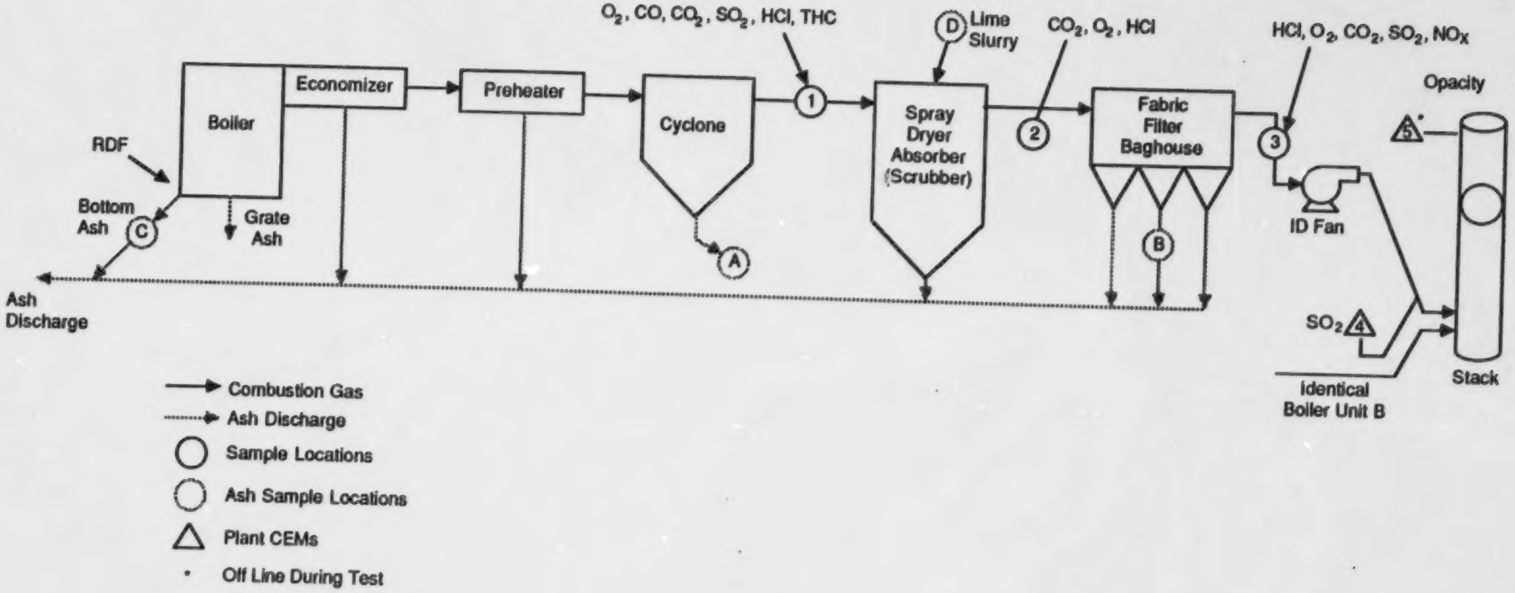
O2, CO, CO2, SO2, HCl, THC
Lime Slurry
D
CO2, O2, HCl
HCl, O2, CO2, SO2, NOx
Opacity
RDF
Boiler
Economizer
Preheater
Cyclone
1
Spray Dryer Absorber (Scrubber)
2
Fabric Filter Baghouse
3
5
Bottom Ash
C
Grate Ash
A
B
ID Fan
Ash Discharge
SO2
4
Stack
Identical Boiler Unit B
Combustion Gas
Ash Discharge
Sample Locations
Ash Sample Locations
Plant CEMs
Off Line During Test

Figure 1-2. Sampling and Monitoring Locations, Unit A.

# SECTION 2.0

# SUMMARY OF EMISSION RESULTS

This section summarizes the results of the test program conducted at the MERC facility in Biddeford, Maine, during the period from December 9 through 12, 1987. Standard international units (SIU) are used to present most of the data. The main exceptions are data related to the process; these are shown in the customary English units. A table providing conversion factors between SIU and English units is provided at the end of this volume. In this section trace organic and metal emissions are normalized to 12% $CO_2$. Sample calculations are given in Appendix A. Uncorrected results and raw data are shown in Appendices B through M.

Note that the nongaseous related results (PCDD/PCDF, particulate mass loading, and metals) do not represent true furnace or uncontrolled emissions because the spray dryer inlet sampling was conducted after a cyclone which removes large particles. However, in this report the term uncontrolled emissions will be used to identify emissions measured at the input to the spray dryer/baghouse control system.

## 2.1 PROCESS DATA

The facility burned 100% RDF at full load conditions without auxiliary fuel during all three test runs. Key operating parameters measured during each test are summarized in Table 2-1. A complete process description is in Section 3.0, Process Description and Operation, and detailed process logging data are in Appendix B, Process Data. One major change in operation occurred during the test series. The lime slurry feed rate was more than doubled about 45 min after the start of run 2 and held at that level for the remaining tests. Facility operators made this change because MRI's continuous emission monitor (CEM) for $SO_2$ at the baghouse outlet was reporting emissions which exceeded the facility operating permit.

Intermittent process problems occurred during all three tests and were primarily related to RDF conveyor feed malfunctions. During test runs 1 and 3 the problems were severe enough to end the test early. In both cases the sampling teams had completed at least two-thirds of the test period, and the partial tests were judged to be acceptable by EPA personnel on site.

None of the process monitoring equipment was calibrated during the test program, although Radian did perform a review of the data and compared readings to the expected design values. With the exception of the plant $SO_2$ monitor, which was not operational during the tests, there were no difficulties encountered with the process monitoring data.

TABLE 2-1. SUMMARY OF KEY OPERATING PARAMETERS DURING THE MERC TEST PROGRAM IN BIDDEFORD, MAINE

| | Run 1 12-09-87 | Run 2 12-10-87 | Run 3 12-12-87 | Average |
|---|---|---|---|---|
| Superheater steam | | | | |
| Flow rate (1,000 lb/h) | 106 | 109 | 108 | 108 |
| Pressure (psig) | 663 | 676 | 671 | 670 |
| Outlet temperature (°F) | 746 | 751 | 748 | 748 |
| Combustion air | | | | |
| Total airflow rate (1,000 lb/h) | 124 | 123 | 134 | 127 |
| Undergrate airflow rate (1,000 lb/h)[a] | 53 | 50 | 63 | 55 |
| Overfire airflow rate (1,000 lb/h) | 71 | 73 | 70 | 71 |
| Overfire air distribution (%)[b] | 57 | 59 | 52 | 56 |
| Undergrate air pressure (in. $H_2O$) | -0.23 | -0.86 | -0.26 | -0.45 |
| Overfire air fan pressure (in. $H_2O$) | 25.3 | 25.6 | 25.0 | 25.3 |
| Air heater inlet air temperature (°F) | 127 | 66 | 118 | 104 |
| Air heater outlet air temperature (°F) | 381 | 368 | 385 | 378 |
| Excess oxygen (% by volume, wet) | | | | |
| Left side | 5.59 | 5.77 | 5.78 | 5.71 |
| Right side | 7.91 | 8.13 | 8.02 | 8.02 |
| Heat release ($10^6$ Btu/h) | | | | |
| Total (RDF + auxiliary fuel) | 150 | 153 | 151 | 151 |
| RDF only | 150 | 153 | 150 | 151 |
| Flue gas temperatures (°F) | | | | |
| Economizer inlet | 779 | 788 | 801 | 789 |
| Economizer outlet/air heater inlet | 515 | 523 | 532 | 523 |
| Air heater outlet | 374 | 363 | 383 | 373 |
| Spray dryer inlet | 374 | 364 | 384 | 374 |
| Spray dryer outlet/fabric filter inlet | 277 | 278 | 279 | 278 |
| Fabric filter outlet | 268 | 268 | 268 | 268 |
| Gas differential pressures (in. $H_2O$) | | | | |
| Undergrate to furnace | 0.46 | 0.34 | 0.44 | 0.41 |
| Dust collector (cyclone) | 3.02 | 3.07 | 3.37 | 3.15 |
| Spray dryer | 4.24 | 4.84 | 5.17 | 4.75 |
| Fabric filter | 7.16 | 7.89 | 8.22 | 7.75 |
| Flue gas pressures (in. $H_2O$) | | | | |
| Spray dryer inlet | -7.20 | -7.25 | -7.39 | -7.28 |
| Spray dryer outlet | -11.5 | -13.1 | -13.4 | -12.7 |
| I.D. fan suction | -18.7 | -21.0 | -21.7 | -20.5 |
| Lime slurry feed rate (gpm) | 2.91 | 6.70 | 7.80 | 5.80 |
| Dilution water feed rate (gpm) | 6.95 | 3.39 | 4.89 | 5.07 |
| Total lime slurry and water feed rate (gpm) | 9.86 | 10.1 | 12.7 | 10.9 |

[a] Undergrate airflow rate was calculated as the difference between the total airflow rate and overfire airflow rate.

[b] Overfire air distribution was calculated as the overfire airflow rate divided by the total airflow rate.

## 2.2 PCDD/PCDF EMISSIONS

Table 2-2 summarizes measured values of PCDD and PCDF at the inlet to the spray dryer (uncontrolled) and the outlet of the baghouse (controlled). Relevant data are presented in Appendix C (field data) and Appendix G (laboratory data). The blank train analyses showed insignificant contamination. Therefore, no blank correction was used. Blank train results are presented in Section 6.2.1.

The PCDF fraction is about twice as large as the PCDD fraction for both controlled and uncontrolled emissions. There is no significant variation among the three runs. The average total PCDD/PCDF emission rate was 55 mg/h (877 ng/dscm) uncontrolled and 0.3 mg/h (4.3 ng/dscm) controlled representing an efficiency of about 99.5% for both the dioxins and furans.

The uncontrolled samples had separate analyses for the front and back halves of the sampling train. The back half fractions showed concentrations near detection limits indicating that the PCDD/PCDF are predominately associated with the particulate matter at the control device inlet. Details of the distribution are given in Appendix G including the GC/MS report sheets for all samples.

Tables 2-3 (uncontrolled) and 2-4 (controlled) show the isomer specific PCDD/PCDF concentrations measured. All 17 specific isomers listed in Table 1-1 are well above detection limits in the uncontrolled samples for each test. For the controlled samples, all 17 isomers were detected in the completed test (run 2), and most were also detected in the two partial runs.

Tables 2-5 (uncontrolled) and 2-6 (controlled) show the PCDD/PCDF congener distribution as mole fractions. Figures 2-1 (uncontrolled) and 2-2 (controlled) are plots of mole fraction vs. chlorine number of each PCDD congener. Figures 2-3 and 2-4 are the mole fraction plots for each PCDF congener. No significant change in the distributions occurred across the control devices.

The EPA 2,3,7,8-PCDD toxic equivalencies[3] are shown in Tables 2-7 (uncontrolled) and 2-8 (controlled). Due to lower equivalent toxicity for furans, the total toxicity is similar for the dioxins and furans. 2,3,7,8-TCDD accounts for about 10% (uncontrolled) to 20% (controlled) of the total toxicity.

Average controlled emissions of PCDD and PCDF are about 45 ng/g and 100 ng/g of particulate, respectively. Although the ratio of PCDD/PCDF to particulate loading is about 20% higher for controlled (Table 2-9) than for uncontrolled (Table 2-10), this is not statistically significant considering the mean and standard deviations of the two data sets.

TABLE 2-2. SUMMARY OF SELECTED PROCESS CONDITIONS AND PCDD/PCDF EMISSIONS FOR MERC

| | Run 1 (12-09-87) | | | Run 2 (12-10-87) | | | Run 3 (12-12-87) | | | Average | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Uncontrolled | Controlled | Control efficiency (%) | Uncontrolled | Controlled | Control efficiency (%) | Uncontrolled | Controlled | Control efficiency (%) | Uncontrolled | Controlled | Control efficiency (%) |
| Flue Gas Characteristics | | | | | | | | | | | | |
| Flow rate (dscfm) | 38,300 | 39,200 | - | 40,500 | 41,100 | - | 41,000 | 42,500 | - | 39,900 | 40,900 | - |
| Temperature (°F) | 371 | 270 | - | 362 | 269 | - | 381 | 272 | - | 371 | 270 | - |
| Moisture (% by volume) | 14.3 | 15.3 | - | 14.4 | 13.5 | - | 16.0 | 17.0 | - | 14.9 | 15.3 | - |
| $CO_2$ (% by volume) | 10.9 | 10.9 | - | 11.0 | 10.9 | - | 11.3 | 11.3 | - | 11.1 | 11.0 | - |
| $O_2$ (% by volume) | 8.6 | 8.6 | - | 8.5 | 8.6 | - | 8.2 | 8.2 | - | 8.4 | 8.5 | - |
| Process Operations | | | | | | | | | | | | |
| Steam load ($10^3$ lb/h) | 106 | 106 | - | 109 | 109 | - | 108 | 108 | - | 108 | 108 | - |
| PCDD Results | | | | | | | | | | | | |
| Total PCDD (ng/dscm) | 217 | 1.25 | 99.42 | 259 | 1.45 | 99.44 | 323 | 0.972 | 99.70 | 266 | 1.22 | 99.54 |
| Total PCDD (corrected to 12% $CO_2$, ng/dscm) | 239 | 1.38 | 99.42 | 282 | 1.59 | 99.44 | 342 | 1.03 | 99.70 | 288 | 1.33 | 99.54 |
| PCDF Results | | | | | | | | | | | | |
| Total PCDF (ng/dscm) | 540 | 2.67 | 99.50 | 514 | 3.14 | 99.38 | 580 | 2.23 | 99.62 | 545 | 2.68 | 99.51 |
| Total PCDF (corrected to 12% $CO_2$, ng/dscm) | 594 | 2.94 | 99.50 | 560 | 3.45 | 99.38 | 615 | 2.36 | 99.62 | 590 | 2.92 | 99.50 |
| PCDD/PCDF Results | | | | | | | | | | | | |
| Total PCDD/PCDF (ng/dscm) | 757 | 3.93 | 99.48 | 772 | 4.58 | 99.40 | 903 | 3.20 | 99.64 | 811 | 3.90 | 99.52 |
| Total PCDD/PCDF (corrected to 12% $CO_2$, ng/dscm) | 833 | 4.32 | 99.48 | 842 | 5.04 | 99.40 | 957 | 3.39 | 99.64 | 877 | 4.25 | 99.51 |
| 2,3,7,8-TCDD toxic equivalent (ng/dscm at 12% $CO_2$)[a] | 11.4 | 0.066 | 99.42 | 12.9 | 0.082 | 99.33 | 13.6 | 0.058 | 99.57 | 12.6 | 0.071 | 99.44 |
| Emission Rates (ug/h) | | | | | | | | | | | | |
| Total PCDD | 14,000 | 83.3 | - | 17,800 | 101 | - | 22,500 | 70.2 | - | 18,100 | 84.8 | - |
| Total PCDF | 35,200 | 178 | - | 35,400 | 219 | - | 40,400 | 161 | - | 37,000 | 186 | - |
| Total PCDD/PCDF | 49,200 | 261 | - | 53,200 | 320 | - | 62,900 | 231 | - | 55,100 | 271 | - |

[a] USEPA. Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of PCDDs/PCDFs. EPA-625/3-87/012.[3]

TABLE 2-3. UNCONTROLLED PCDD/PCDF EMISSIONS

| Isomer | Uncorrected (ng/dscm) |  |  |  | Corrected to 12% $CO_2$ (ng/dscm)[a] |  |  |  |
|---|---|---|---|---|---|---|---|---|
|  | Run 1 | Run 2 | Run 3 | Average | Run 1 | Run 2 | Run 3 | Average |
| Dioxins |  |  |  |  |  |  |  |  |
| 2,3,7,8-TCDD | 0.72 | 1.5 | 1.5 | 1.2 | 0.80 | 1.6 | 1.6 | 1.3 |
| Other TCDD | 32 | 40 | 48 | 40 | 35 | 43 | 51 | 43 |
| 1,2,3,7,8-PeCDD | 3.9 | 4.3 | 5.0 | 4.4 | 4.3 | 4.7 | 5.3 | 4.8 |
| Other PeCDD | 35 | 43 | 62 | 47 | 39 | 47 | 66 | 51 |
| 1,2,3,4,7,8-HxCDD | 4.1 | 5.3 | 6.0 | 5.1 | 4.5 | 5.8 | 6.4 | 5.6 |
| 1,2,3,6,7,8-HxCDD | 8.1 | 11 | 12 | 10.1 | 8.9 | 12 | 12 | 10.9 |
| 1,2,3,7,8,9-HxCDD | 6.7 | 9.1 | 10.2 | 8.6 | 7.3 | 9.9 | 11 | 9.3 |
| Other HxCDD | 39 | 52 | 62 | 51 | 43 | 57 | 66 | 56 |
| 1,2,3,4,6,7,8-HpCDD | 25 | 26 | 34 | 28 | 27 | 28 | 36 | 31 |
| Other HpCDD | 21 | 24 | 32 | 26 | 23 | 26 | 34 | 28 |
| OCDD | 41 | 43 | 49 | 44 | 45 | 47 | 52 | 48 |
| Total PCDD | 217 | 259 | 323 | 266 | 239 | 282 | 342 | 288 |
| Furans |  |  |  |  |  |  |  |  |
| 2,3,7,8-TCDF | 29 | 30 | 32 | 30 | 32 | 33 | 34 | 33 |
| Other TCDF | 199 | 182 | 192 | 191 | 219 | 198 | 204 | 207 |
| 1,2,3,4,8-PeCDF | 2.9 | 3.7 | 3.5 | 3.4 | 3.2 | 4.0 | 3.8 | 3.7 |
| 1,2,3,7,8-PeCDF | 14 | 14 | 13 | 13.7 | 16 | 15 | 14 | 15 |
| 2,3,4,7,8-PeCDF | 14 | 14 | 15 | 14.3 | 15 | 16 | 16 | 16 |
| Other PeCDF | 130 | 129 | 141 | 133 | 144 | 140 | 150 | 144 |
| 1,2,3,4,7,8-HxCDF | 16 | 17 | 20 | 18 | 18 | 18 | 21 | 19 |
| 1,2,3,6,7,8-HxCDF | 9.6 | 10 | 10 | 10.2 | 10.6 | 11 | 11 | 11 |
| 1,2,3,4,7,9-HxCDF | 2.0 | 2.2 | 2.5 | 2.3 | 2.2 | 2.4 | 2.7 | 2.4 |
| 2,3,4,6,7,8-HxCDF | 8.3 | 5.0 | 13 | 8.9 | 9.1 | 5.5 | 14 | 9.6 |
| 1,2,3,7,8,9-HxCDF | 2.1 | 1.0 | 1.2 | 1.4 | 2.3 | 1.1 | 1.3 | 1.6 |
| Other HxCDF | 53 | 48 | 62 | 54 | 58 | 52 | 66 | 59 |
| 1,2,3,4,6,7,8-HpCDF | 31 | 28 | 35 | 31 | 34 | 30 | 37 | 34 |
| 1,2,3,4,7,8,9-HpCDF | 5.0 | 4.7 | 6.6 | 5.4 | 5.5 | 5.1 | 6.9 | 5.8 |
| Other HpCDF | 13 | 13 | 17 | 14 | 14 | 14 | 18 | 15 |
| OCDF | 12 | 12 | 16 | 13 | 13 | 13 | 17 | 14 |
| Total PCDF | 540 | 513 | 580 | 545 | 594 | 560 | 615 | 590 |
| Total PCDD + PCDF | 758 | 772 | 903 | 811 | 833 | 842 | 957 | 877 |
| $CO_2$ correction factor[a] | 1.1 | 1.09 | 1.06 |  |  |  |  |  |

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[a] $CO_2$ correction factor x measured value = value corrected (normalized) to 12% $CO_2$.

TABLE 2-4. CONTROLLED PCDD/PCDF EMISSIONS

| Isomer | Uncorrected (ng/dscm) |  |  |  | Corrected to 12% $CO_2$ (ng/dscm)[b] |  |  |  |
|---|---|---|---|---|---|---|---|---|
|  | Run 1 | Run 2 | Run 3 | Average | Run 1 | Run 2 | Run 3 | Average |
| Dioxins |  |  |  |  |  |  |  |  |
| 2,3,7,8-TCDD | 0.013 | 0.031 | 0.11[a] | 0.015 | 0.014 | 0.034 | 0.011[a] | 0.016 |
| Other TCDD | 0.17 | 0.17 | 0.11 | 0.15 | 0.19 | 0.19 | 0.11 | 0.16 |
| 1,2,3,7,8-PeCDD | 0.020 | 0.021 | 0.023 | 0.021 | 0.022 | 0.023 | 0.024 | 0.023 |
| Other PeCDD | 0.18 | 0.31 | 0.11 | 0.20 | 0.20 | 0.34 | 0.12 | 0.22 |
| 1,2,3,4,7,8-HxCDD | 0.019 | 0.022 | 0.022 | 0.021 | 0.021 | 0.024 | 0.023 | 0.023 |
| 1,2,3,6,7,8-HxCDD | 0.042 | 0.047 | 0.041 | 0.044 | 0.047 | 0.052 | 0.043 | 0.047 |
| 1,2,3,7,8,9-HxCDD | 0.033 | 0.042 | 0.035 | 0.037 | 0.037 | 0.046 | 0.037 | 0.040 |
| Other HxCDD | 0.21 | 0.21 | 0.13 | 0.18 | 0.23 | 0.23 | 0.13 | 0.20 |
| 1,2,3,4,6,7,8-HpCDD | 0.14 | 0.16 | 0.13 | 0.14 | 0.16 | 0.18 | 0.13 | 0.15 |
| Other HpCDD | 0.13 | 0.14 | 0.11 | 0.13 | 0.14 | 0.15 | 0.12 | 0.14 |
| OCDD | 0.29 | 0.29 | 0.27 | 0.28 | 0.32 | 0.32 | 0.28 | 0.31 |
| Total PCDD | 1.3 | 1.4 | 0.98 | 1.2 | 1.4 | 1.6 | 1.0 | 1.3 |
| Furans |  |  |  |  |  |  |  |  |
| 2,3,7,8-TCDF | 0.14 | 0.14 | 0.14 | 0.14 | 0.15 | 0.15 | 0.15 | 0.15 |
| Other TCDF | 0.90 | 0.85 | 0.75 | 0.83 | 0.99 | 0.94 | 0.80 | 0.91 |
| 1,2,3,4,8-PeCDF | 0.016 | 0.016 | 0.011 | 0.014 | 0.017 | 0.018 | 0.012 | 0.016 |
| 1,2,3,7,8-PeCDF | 0.063 | 0.065 | 0.044 | 0.057 | 0.069 | 0.071 | 0.046 | 0.062 |
| 2,3,4,7,8-PeCDF | 0.064 | 0.059 | 0.055 | 0.059 | 0.070 | 0.065 | 0.058 | 0.064 |
| Other PeCDF | 0.69 | 0.63 | 0.53 | 0.61 | 0.75 | 0.69 | 0.56 | 0.67 |
| 1,2,3,4,7,8-HxCDF | 0.093 | 0.089 | 0.088 | 0.090 | 0.10 | 0.98 | 0.094 | 0.098 |
| 1,2,3,6,7,8-HxCDF | 0.048 | 0.051 | 0.043 | 0.047 | 0.052 | 0.056 | 0.046 | 0.051 |
| 1,2,3,4,7,9-HxCDF | 0.014[a] | 0.0064 | 0.035[a] | 0.0021 | 0.016[a] | 0.0070 | 0.037[a] | 0.0023 |
| 2,3,4,6,7,8,-HxCDF | 0.055 | 0.038 | 0.042 | 0.045 | 0.060 | 0.042 | 0.045 | 0.049 |
| 1,2,3,7,8,9-HxCDF | 0.0037 | 0.0055 | 0.010[a] | 0.0031 | 0.0041 | 0.006 | 0.011[a] | 0.0034 |
| Other HxCDF | 0.28 | 0.29 | 0.22 | 0.26 | 0.31 | 0.32 | 0.23 | 0.28 |
| 1,2,3,4,6,7,8,-HpCDF | 0.17 | 0.16 | 0.15 | 0.16 | 0.18 | 0.181 | 0.16 | 0.18 |
| 1,2,3,4,7,8,9-HpCDF | 0.031 | 0.035 | 0.033 | 0.033 | 0.034 | 0.038 | 0.035 | 0.036 |
| Other HpCDF | 0.067 | 0.066 | 0.059 | 0.064 | 0.074 | 0.072 | 0.062 | 0.069 |
| OCDF | 0.070 | 0.64 | 0.059 | 0.26 | 0.077 | 0.70 | 0.062 | 0.28 |
| Total PCDF | 2.7 | 3.1 | 2.3 | 2.7 | 3.0 | 3.5 | 2.4 | 2.9 |
| Total PCDD + PCDF | 3.9 | 4.6 | 3.3 | 3.9 | 4.3 | 5.0 | 3.5 | 4.3 |
| $CO_2$ correction factor[b] | 1.1 | 1.1 | 1.06 |  |  |  |  |  |

[a] Denotes detection limits of undetected compounds which are considered zeroes in calculating averages.

[b] $CO_2$ correction factor x measured value = value corrected (normalized) to 12% $CO_2$.

## TABLE 2-5. UNCONTROLLED FLUE GAS PCDD/PCDF CONGENER DISTRIBUTION

| Isomer | Molecular weight | Mole fraction[a] | | | |
|---|---|---|---|---|---|
| | | Run 1 | Run 2 | Run 3 | Average |
| **Dioxins** | | | | | |
| 2,3,7,8-TCDD | 320 | 0.004 | 0.007 | 0.006 | 0.005 |
| Other TCDD | 320 | 0.180 | 0.183 | 0.180 | 0.181 |
| 1,2,3,7,8-PeCDD | 354 | 0.020 | 0.018 | 0.017 | 0.018 |
| Other PeCDD | 354 | 0.177 | 0.182 | 0.209 | 0.189 |
| 1,2,3,4,7,8-HxCDD | 388 | 0.019 | 0.020 | 0.018 | 0.019 |
| 1,2,3,6,7,8-HxCDD | 388 | 0.037 | 0.040 | 0.035 | 0.038 |
| 1,2,3,7,8,9-HxCDD | 388 | 0.031 | 0.035 | 0.031 | 0.032 |
| Other HxCDD | 388 | 0.180 | 0.200 | 0.191 | 0.191 |
| 1,2,3,4,6,7,8-HpCDD | 422 | 0.103 | 0.091 | 0.096 | 0.097 |
| Other HpCDD | 422 | 0.090 | 0.085 | 0.089 | 0.088 |
| OCDD | 456 | 0.160 | 0.139 | 0.127 | 0.142 |
| **Furans** | | | | | |
| 2,3,7,8-TCDF | 304 | 0.059 | 0.065 | 0.062 | 0.062 |
| Other TCDF | 304 | 0.404 | 0.389 | 0.367 | 0.387 |
| 1,2,3,4,8-PeCDF | 338 | 0.005 | 0.007 | 0.006 | 0.006 |
| 1,2,3,7,8-PeCDF | 338 | 0.026 | 0.027 | 0.023 | 0.025 |
| 2,3,4,7,8-PeCDF | 338 | 0.025 | 0.028 | 0.025 | 0.026 |
| Other PeCDF | 338 | 0.239 | 0.248 | 0.242 | 0.243 |
| 1,2,3,4,7,8-HxCDF | 372 | 0.027 | 0.029 | 0.032 | 0.029 |
| 1,2,3,6,7,8-HxCDF | 372 | 0.016 | 0.018 | 0.016 | 0.017 |
| 1,2,3,4,7,9-HxCDF | 372 | 0.003 | 0.004 | 0.004 | 0.004 |
| 2,3,4,6,7,8-HxCDF | 372 | 0.014 | 0.009 | 0.021 | 0.014 |
| 1,2,3,7,8,9-HxCDF | 372 | 0.003 | 0.002 | 0.002 | 0.002 |
| Other HxCDF | 372 | 0.087 | 0.084 | 0.097 | 0.089 |
| 1,2,3,4,6,7,8-HpCDF | 406 | 0.047 | 0.045 | 0.050 | 0.047 |
| 1,2,3,4,7,8,9-HpCDF | 406 | 0.008 | 0.008 | 0.009 | 0.008 |
| Other HpCDF | 406 | 0.019 | 0.020 | 0.024 | 0.021 |
| OCDF | 440 | 0.016 | 0.017 | 0.021 | 0.018 |

[a] Mole fraction of each homolog is based on the tetra- thru octa- homologs. PCDD mole fractions are based on total PCDD, and PCDF mole fractions are based on total PCDF.

## TABLE 2-6. CONTROLLED FLUE GAS PCDD/PCDF CONGENER DISTRIBUTION

| Isomer | Molecular weight | Mole fraction[a] Run 1 | Run 2 | Run 3 | Average |
|---|---|---|---|---|---|
| Dioxins | | | | | |
| 2,3,7,8-TCDD | 320 | 0.013 | 0.026 | 0.013[b] | 0.013 |
| Other TCDD | 320 | 0.170 | 0.144 | 0.134 | 0.149 |
| 1,2,3,7,8-PeCDD | 354 | 0.018 | 0.016 | 0.026 | 0.020 |
| Other PeCDD | 354 | 0.158 | 0.234 | 0.130 | 0.174 |
| 1,2,3,4,7,8-HxCDD | 388 | 0.015 | 0.015 | 0.023 | 0.018 |
| 1,2,3,6,7,8-HxCDD | 388 | 0.034 | 0.033 | 0.042 | 0.036 |
| 1,2,3,7,8,9-HxCDD | 388 | 0.027 | 0.029 | 0.036 | 0.030 |
| Other HxCDD | 388 | 0.166 | 0.145 | 0.131 | 0.148 |
| 1,2,3,4,6,7,8-HpCDD | 422 | 0.105 | 0.101 | 0.120 | 0.108 |
| Other HpCDD | 422 | 0.093 | 0.088 | 0.106 | 0.095 |
| OCDD | 456 | 0.202 | 0.171 | 0.237 | 0.203 |
| Furans | | | | | |
| 2,3,7,8-TCDF | 304 | 0.058 | 0.052 | 0.069 | 0.059 |
| Other TCDF | 304 | 0.369 | 0.315 | 0.367 | 0.350 |
| 1,2,3,4,8-PeCDF | 338 | 0.006 | 0.005 | 0.005 | 0.005 |
| 1,2,3,7,8-PeCDF | 338 | 0.023 | 0.021 | 0.019 | 0.021 |
| 2,3,4,7,8-PeCDF | 338 | 0.023 | 0.020 | 0.024 | 0.022 |
| Other PeCDF | 338 | 0.254 | 0.208 | 0.232 | 0.231 |
| 1,2,3,4,7,8-HxCDF | 372 | 0.031 | 0.027 | 0.035 | 0.031 |
| 1,2,3,6,7,8-HxCDF | 372 | 0.016 | 0.015 | 0.017 | 0.016 |
| 1,2,3,4,7,9-HxCDF | 372 | 0.005[b] | 0.002 | 0.014[b] | 0.001 |
| 2,3,4,6,7,8-HxCDF | 372 | 0.018 | 0.011 | 0.017 | 0.016 |
| 1,2,3,7,8,9-HxCDF | 372 | 0.001 | 0.002 | 0.004[b] | 0.001 |
| Other HxCDF | 372 | 0.093 | 0.086 | 0.088 | 0.089 |
| 1,2,3,4,6,7,8-HpCDF | 406 | 0.052 | 0.045 | 0.056 | 0.051 |
| 1,2,3,4,7,8,9-HpCDF | 406 | 0.01 | 0.009 | 0.012 | 0.010 |
| Other HpCDF | 406 | 0.021 | 0.018 | 0.021 | 0.020 |
| OCDF | 440 | 0.020 | 0.163 | 0.020 | 0.068 |

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[a] Mole fraction of each homolog is based on the tetra- thru octa- homologs. PCDD mole fractions are based on total PCDD, and PCDF mole fractions are based on total PCDF.

[b] Compound not detected. Value is based upon detection limit and is considered zero in calculating averages.

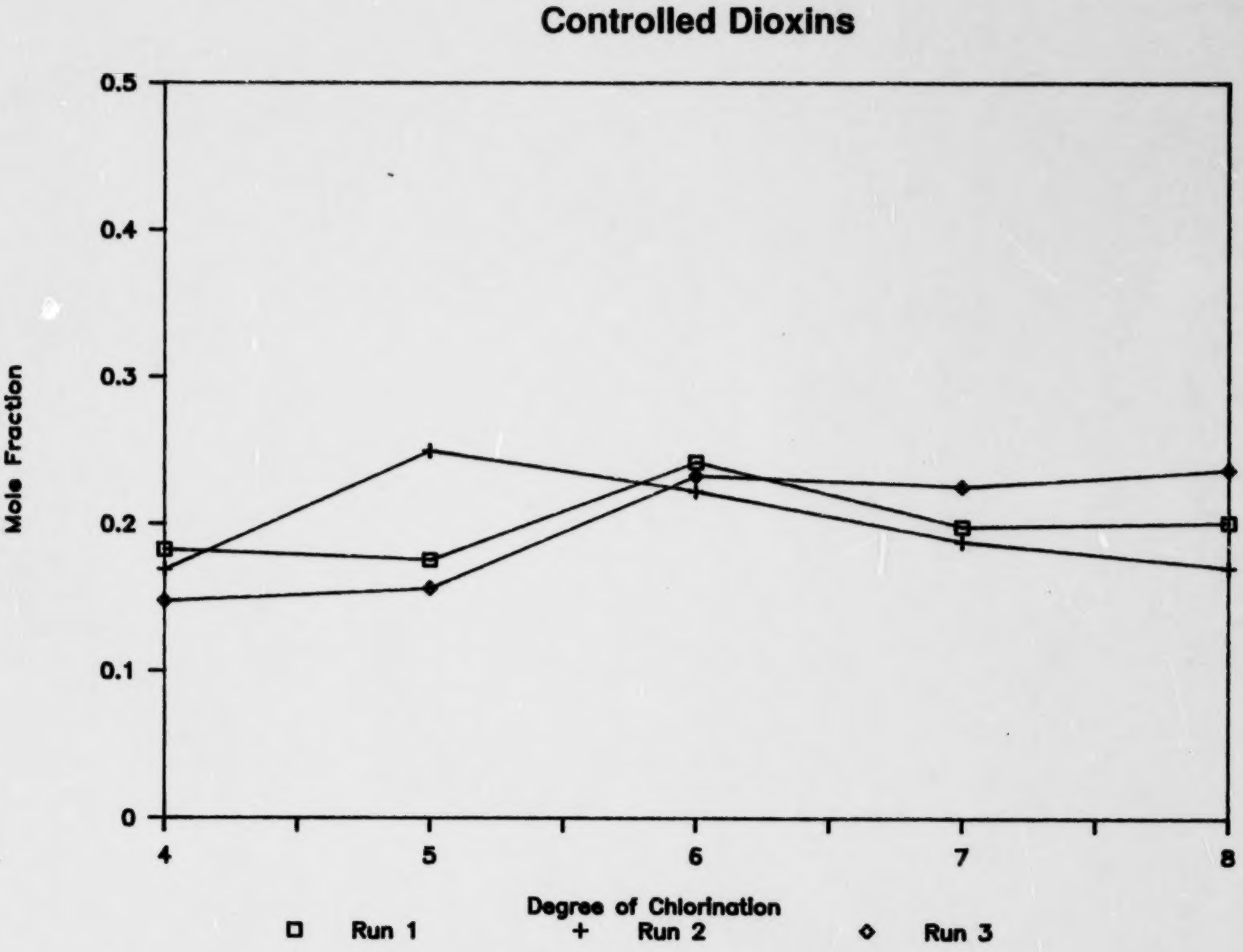

Figure 2-1. Mole Fraction Plot of PCDD (Controlled).

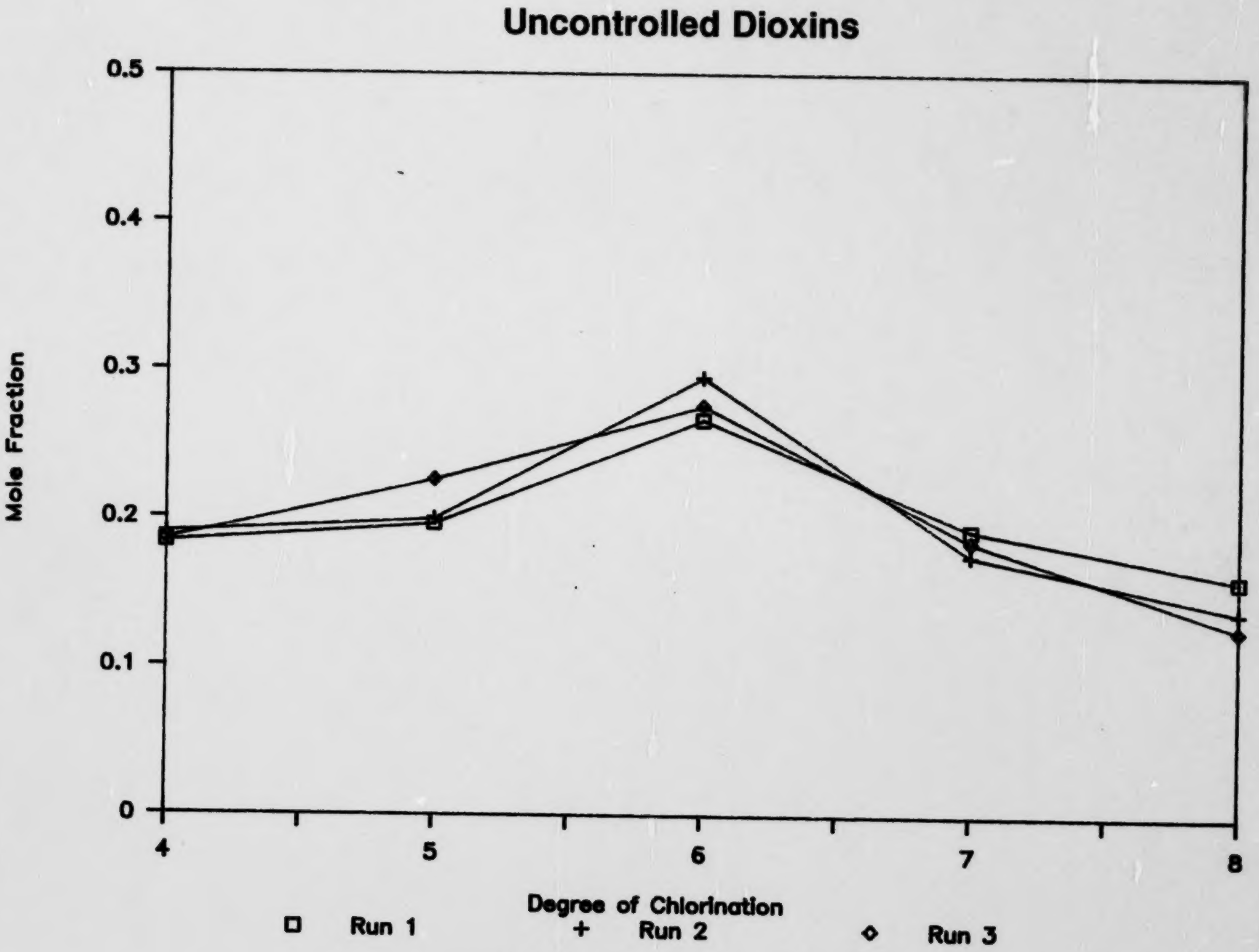

Figure 2-2. Mole Fraction Plot of PCDD (Uncontrolled).

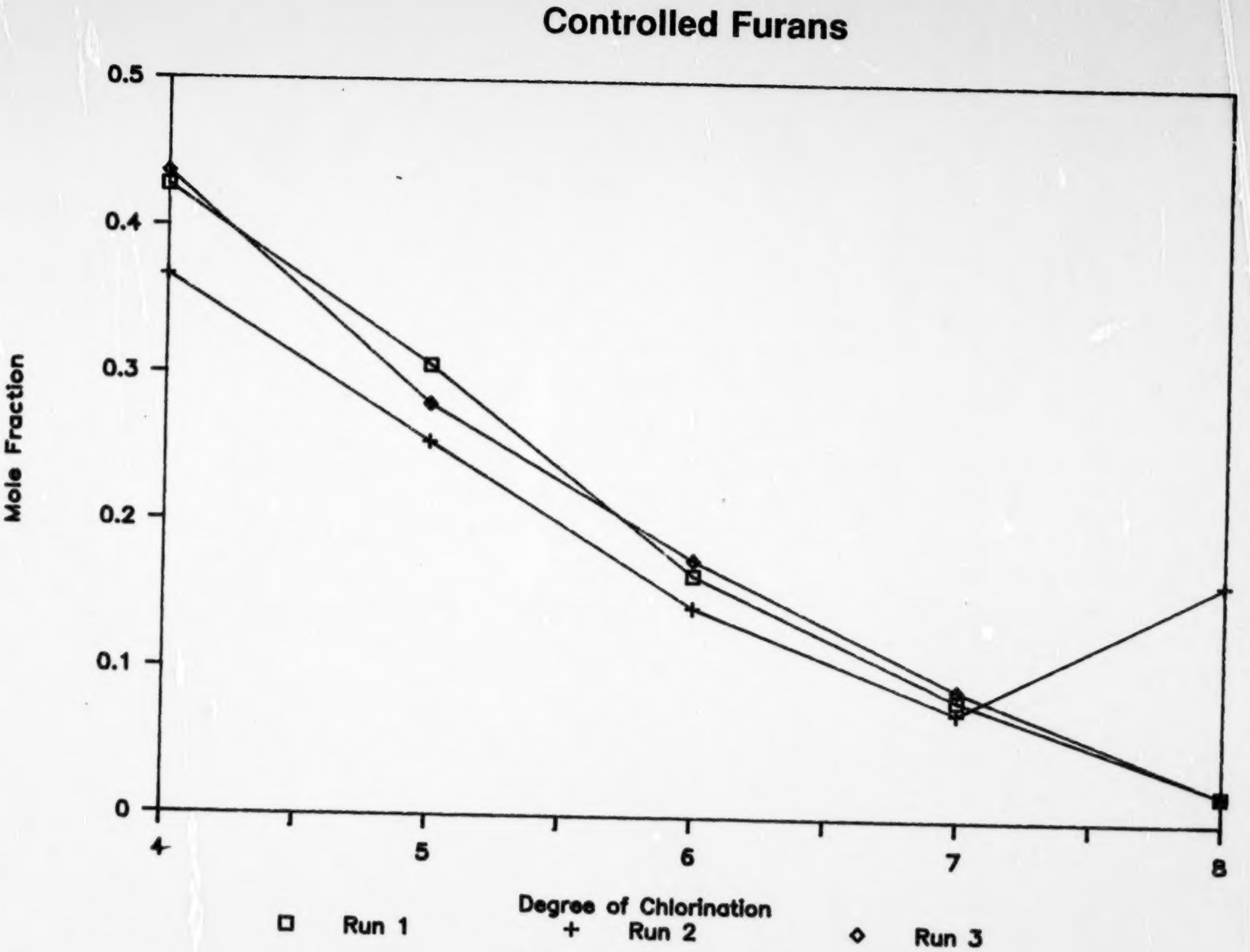

Figure 2-3. Mole Fraction Plot of PCDF (Controlled).

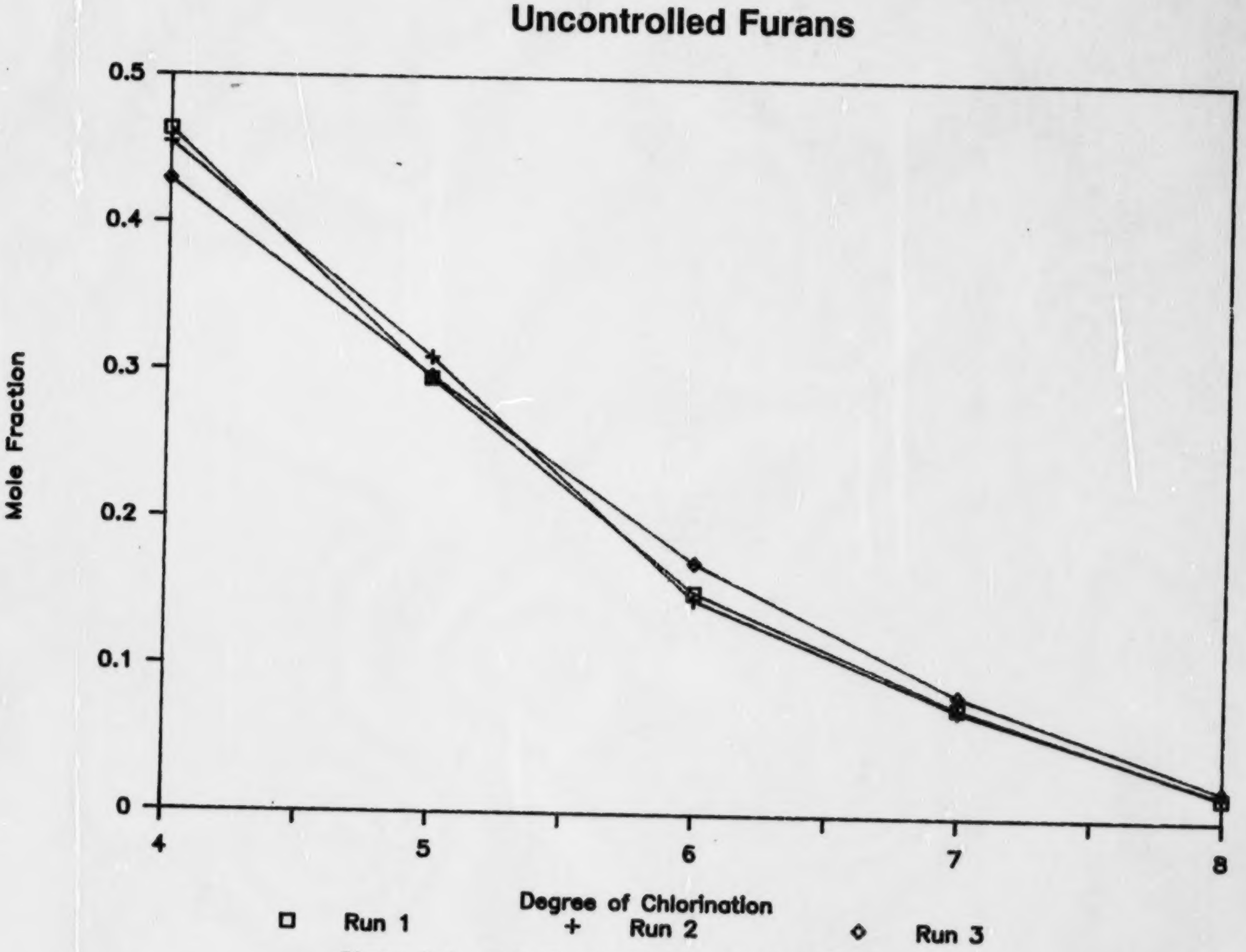

Figure 2-4. Mole Fraction Plot of PCDF (Uncontrolled).

## TABLE 2-7. 2,3,7,8-TCDD TOXIC EQUIVALENCIES OF UNCONTROLLED EMISSIONS

| Isomer | Toxic[a] equiv. | ng/dscm, corrected to 12% $CO_2$ | | | |
|---|---|---|---|---|---|
| | | Run 1 | Run 2 | Run 3 | Average |
| Dioxins | | | | | |
| 2,3,7,8-TCDD | 1 | 0.80 | 1.6 | 1.6 | 1.3 |
| Other TCDD | 0.01 | 0.36 | 0.43 | 0.51 | 0.43 |
| 1,2,3,7,8-PeCDD | 0.5 | 2.1 | 2.3 | 2.65 | 2.4 |
| Other PeCDD | 0.005 | 0.19 | 0.24 | 0.33 | 0.25 |
| 1,2,3,4,7,8-HxCDD | 0.04 | 0.18 | 0.23 | 0.26 | 0.22 |
| 1,2,3,6,7,8-HxCDD | 0.04 | 0.36 | 0.46 | 0.49 | 0.44 |
| 1,2,3,7,8,9-HxCDD | 0.04 | 0.29 | 0.39 | 0.43 | 0.37 |
| Other HxCDD | 0.0004 | 0.017 | 0.023 | 0.027 | 0.02 |
| 1,2,3,4,6,7,8-HpCDD | 0.001 | 0.027 | 0.028 | 0.036 | 0.030 |
| Other HpCDD | 0.00001 | 0 | 0 | 0 | 0 |
| OCDD | 0 | 0 | 0 | 0 | 0 |
| Total PCDD | | 4.4 | 5.7 | 6.3 | 5.5 |
| Furans | | | | | |
| 2,3,7,8-TCDF | 0.1 | 3.2 | 3.3 | 3.4 | 3.3 |
| Other TCDF | 0.001 | 0.22 | 0.20 | 0.20 | 0.21 |
| 1,2,3,4,8-PeCDF | 0.001 | 0.0030 | 0.004 | 0.004 | 0 |
| 1,2,3,7,8-PeCDF | 0.1 | 1.6 | 1.5 | 1.4 | 1.5 |
| 2,3,4,7,8-PeCDF | 0.1 | 1.5 | 1.6 | 1.6 | 1.6 |
| Other PeCDF | 0.001 | 0.14 | 0.14 | 0.15 | 0.14 |
| 1,2,3,4,7,8-HxCDF | 0.01 | 0.18 | 0.18 | 0.21 | 0.19 |
| 1,2,3,6,7,8-HxCDF | 0.01 | 0.11 | 0.11 | 0.11 | 0.11 |
| 1,2,3,4,7,9-HxCDF | 0.0001 | 0 | 0 | 0 | 0 |
| 2,3,4,6,7,8-HxCDF | 0.01 | 0.091 | 0.055 | 0.14 | 0.10 |
| 1,2,3,7,8,9-HxCDF | 0.01 | 0.023 | 0.011 | 0.013 | 0.02 |
| Other HxCDF | 0.0001 | 0.006 | 0.005 | 0.007 | 0.01 |
| 1,2,3,4,6,7,8-HpCDF | 0.001 | 0.034 | 0.030 | 0.037 | 0.03 |
| 1,2,3,4,7,8,9-HpCDF | 0.001 | 0.005 | 0.005 | 0.007 | 0.01 |
| Other HpCDF | 0.00001 | 0 | 0 | 0 | 0 |
| OCDF | 0 | 0 | 0 | 0 | 0 |
| Total PCDF | | 7.1 | 7.1 | 7.3 | 7.2 |
| Total PCDD + PCDF | | 11.4 | 12.9 | 13.6 | 12.6 |

[a] Toxic equivalent method used.

## TABLE 2-8. 2,3,7,8-TCDD TOXIC EQUIVALENCIES OF CONTROLLED EMISSIONS

| Isomer | Toxic[a] equiv. | ng/dscm, corrected to 12% $CO_2$ | | | |
|---|---|---|---|---|---|
| | | Run 1 | Run 2 | Run 3 | Average |
| **Dioxins** | | | | | |
| 2,3,7,8-TCDD | 1 | 0.014 | 0.034 | 0.011[b] | 0.016 |
| Other TCDD | 0.01 | 0.0019 | 0.0019 | 0.0011 | 0.0016 |
| 1,2,3,7,8-PeCDD | 0.5 | 0.011 | 0.012 | 0.012 | 0.012 |
| Other PeCDD | 0.005 | 0.0010 | 0.0017 | 0.0006 | 0.0011 |
| 1,2,3,4,7,8-HxCDD | 0.04 | 0.0008 | 0.0009 | 0.0009 | 0.0009 |
| 1,2,3,6,7,8-HxCDD | 0.04 | 0.0019 | 0.0021 | 0.0017 | 0.0019 |
| 1,2,3,7,8,9-HxCDD | 0.04 | 0.0015 | 0.0018 | 0.0015 | 0.0016 |
| Other HxCDD | 0.0004 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| 1,2,3,4,6,7,8-HpCDD | 0.001 | 0.0002 | 0.0002 | 0.0001 | 0.0002 |
| Other HpCDD | 0.00001 | 0 | 0 | 0 | 0 |
| OCDD | 0 | 0 | 0 | 0 | 0 |
| Total PCDD | | 0.033 | 0.054 | 0.029 | 0.039 |
| **Furans** | | | | | |
| 2,3,7,8-TCDF | 0.1 | 0.015 | 0.015 | 0.015 | 0.015 |
| Other TCDF | 0.001 | 0.0010 | 0.0009 | 0.0008 | 0.0009 |
| 1,2,3,4,8-PeCDF | 0.001 | 0 | 0 | 0 | 0 |
| 1,2,3,7,8-PeCDF | 0.1 | 0.0069 | 0.0071 | 0.0046 | 0.0062 |
| 2,3,4,7,8-PeCDF | 0.1 | 0.0070 | 0.0065 | 0.0058 | 0.0064 |
| Other PeCDF | 0.001 | 0.0008 | 0.0007 | 0.0006 | 0.0007 |
| 1,2,3,4,7,8-HxCDF | 0.01 | 0.0010 | 0.0010 | 0.0009 | 0.0010 |
| 1,2,3,6,7,8-HxCDF | 0.01 | 0.0005 | 0.0006 | 0.0005 | 0.0005 |
| 1,2,3,4,7,9-HxCDF | 0.0001 | 0.0000[b] | 0 | 0.0000[b] | 0 |
| 2,3,4,6,7,8-HxCDF | 0.01 | 0.0006 | 0.0004 | 0.0004 | 0.0005 |
| 1,2,3,7,8,9-HxCDF | 0.01 | 0 | 0.0001 | 0.0001[b] | 0.0000 |
| Other HxCDF | 0.0001 | 0 | 0 | 0 | 0 |
| 1,2,3,4,6,7,8-HpCDF | 0.001 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| 1,2,3,4,7,8,9-HpCDF | 0.001 | 0 | 0 | 0 | 0 |
| Other HpCDF | 0.00001 | 0 | 0 | 0 | 0 |
| OCDF | 0 | 0 | 0 | 0 | 0 |
| Total PCDF | | 0.034 | 0.033 | 0.029 | 0.032 |
| Total PCDD + PCDF | | 0.066 | 0.087 | 0.058 | 0.071 |

[a] See reference 3.

[b] Denotes detection limits of undetected compounds, which are considered zeros in calculating averages.

## TABLE 2-9. RATIO OF UNCONTROLLED PCDD/PCDF TO PARTICULATE EMISSIONS

| Isomer | ng analyte/g particulate | | | |
|---|---|---|---|---|
| | Run 1 | Run 2 | Run 3 | Average |
| **Dioxins** | | | | |
| 2,3,7,8-TCDD | 0.11 | 0.24 | 0.20 | 0.18 |
| Other TCDD | 4.8 | 6.6 | 6.4 | 5.9 |
| 1,2,3,7,8-PeCDD | 0.58 | 0.71 | 0.66 | 0.65 |
| Other PeCDD | 5.2 | 7.2 | 8.2 | 6.9 |
| 1,2,3,4,7,8-HxCDD | 0.60 | 0.88 | 0.79 | 0.76 |
| 1,2,3,6,7,8-HxCDD | 1.2 | 1.8 | 1.5 | 1.5 |
| 1,2,3,7,8,9-HxCDD | 0.99 | 1.5 | 1.3 | 1.3 |
| Other HxCDD | 5.8 | 8.7 | 8.2 | 7.6 |
| 1,2,3,4,6,7,8-HpCDD | 3.6 | 4.3 | 4.5 | 4.1 |
| Other HpCDD | 3.2 | 4.0 | 4.2 | 3.8 |
| OCDD | 6.1 | 7.1 | 6.4 | 6.5 |
| Total PCDD | 32 | 43 | 42 | 39 |
| **Furans** | | | | |
| 2,3,7,8-TCDF | 4.3 | 5.1 | 4.2 | 4.52 |
| Other TCDF | 29 | 30 | 25 | 28 |
| 1,2,3,4,8-PeCDF | 0.44 | 0.61 | 0.46 | 0.50 |
| 1,2,3,7,8-PeCDF | 2.1 | 2.3 | 1.7 | 2.04 |
| 2,3,4,7,8-PeCDF | 2.0 | 2.4 | 1.9 | 2.13 |
| Other PeCDF | 19 | 21 | 18 | 19.76 |
| 1,2,3,4,7,8-HxCDF | 2.4 | 2.8 | 2.6 | 2.62 |
| 1,2,3,6,7,8-HxCDF | 1.4 | 1.7 | 1.4 | 1.51 |
| 1,2,3,4,7,9-HxCDF | 0.30 | 0.37 | 0.33 | 0.33 |
| 2,3,4,6,7,8-HxCDF | 1.2 | 0.83 | 1.7 | 1.27 |
| 1,2,3,7,8,9-HxCDF | 0.30 | 0.17 | 0.16 | 0.21 |
| Other HxCDF | 7.8 | 8.0 | 8.1 | 7.98 |
| 1,2,3,4,6,7,8-HpCDF | 4.6 | 4.6 | 4.5 | 4.60 |
| 1,2,3,4,7,8,9-HpCDF | 0.74 | 0.78 | 0.86 | 0.79 |
| Other HpCDF | 1.9 | 2.1 | 2.2 | 2.06 |
| OCDF | 1.7 | 2.0 | 2.0 | 1.90 |
| Total PCDF | 80 | 86 | 76 | 81 |
| Total PCDD + PCDF | 112 | 129 | 118 | 120 |
| Particulate loading (g/dscm) | 7.414 | 6.538 | 8.099 | |

## TABLE 2-10. RATIO OF CONTROLLED PCDD/PCDF TO PARTICULATE EMISSIONS

| | ng analyte/g particulate | | | |
|---|---|---|---|---|
| Isomer | Run 1 | Run 2 | Run 3 | Average |
| Dioxins | | | | |
| 2,3,7,8-TCDD | 0.65 | 1.0 | 0.25[a] | 0.56 |
| Other TCDD | 8.8 | 5.8 | 2.5 | 5.7 |
| 1,2,3,7,8-PeCDD | 1.0 | 0.71 | 0.55 | 0.76 |
| Other PeCDD | 9.0 | 10 | 2.7 | 7.4 |
| 1,2,3,4,7,8-HxCDD | 0.96 | 0.73 | 0.53 | 0.74 |
| 1,2,3,6,7,8-HxCDD | 2.1 | 1.6 | 0.97 | 1.6 |
| 1,2,3,7,8,9-HxCDD | 1.7 | 1.4 | 0.82 | 1.3 |
| Other HxCDD | 10 | 7.2 | 3.0 | 6.8 |
| 1,2,3,4,6,7,8-HpCDD | 7.1 | 5.4 | 3.0 | 5.2 |
| Other HpCDD | 6.3 | 4.7 | 2.6 | 4.6 |
| OCDD | 15 | 9.8 | 6.4 | 10 |
| Total PCDD | 63 | 49 | 23 | 45 |
| Furans | | | | |
| 2,3,7,8-TCDF | 7.0 | 4.7 | 3.4 | 5.0 |
| Other TCDF | 45 | 29 | 18 | 31 |
| 1,2,3,4,8-PeCDF | 0.79 | 0.55 | 0.27 | 0.53 |
| 1,2,3,7,8-PeCDF | 3.1 | 2.2 | 1.0 | 2.1 |
| 2,3,4,7,8-PeCDF | 3.2 | 2.0 | 1.3 | 2.2 |
| Other PeCDF | 34 | 21 | 13 | 23 |
| 1,2,3,4,7,8-HxCDF | 4.7 | 3.0 | 2.1 | 3.3 |
| 1,2,3,6,7,8-HxCDF | 2.4 | 1.7 | 1.0 | 1.7 |
| 1,2,3,4,7,9-HxCDF | 0.72[a] | 0.21 | 0.83[a] | 0.07 |
| 2,3,4,6,7,8-HxCDF | 2.7 | 1.3 | 1.0 | 1.7 |
| 1,2,3,7,8,9-HxCDF | 0.19 | 0.18 | 0.25[a] | 0.12 |
| Other HxCDF | 14 | 9.6 | 5.2 | 9.6 |
| 1,2,3,4,6,7,8-HpCDF | 8.4 | 5.6 | 3.6 | 5.9 |
| 1,2,3,4,7,8,9-HpCDF | 1.5 | 1.2 | 0.78 | 1.2 |
| Other HpCDF | 3.4 | 2.2 | 1.4 | 2.3 |
| OCDF | 3.5 | 22 | 1.4 | 8.8 |
| Total PCDF | 135 | 106 | 54 | 98 |
| Total PCDD + PCDF | 198 | 155 | 78 | 143 |
| Particulate loading (g/dscm) | 0.0219 | 0.0326 | 0.0445 | |

---

[a] Based on detection limit of compound; considered as zero in calculating averages.

## 2.3 PARTICULATE EMISSIONS

Particulate mass loading was determined by gravimetric analysis of the filter, cyclone, and front half acetone rinses of the metals train. After reaching constant weight, these fractions were digested for metals analysis. Particulate emissions are summarized in Table 2-11. Particulate results were blank corrected as specified in EPA Method 5. The PM control efficiency for the SD/FF averaged about 99.5% for the three runs.

Field data are in Appendix D and the laboratory analyses are in Appendix H. Further calibration data are in Section 6.0 and Appendix J.

## 2.4 METALS EMISSIONS

Table 2-12 summarizes the emission data for selected hazardous metals (As, Cd, Cr, Pb, and Hg). Field data are presented in Appendix D, and relevant laboratory data are presented in Appendix H. No blank corrections were used, except for mercury. As and Cr were below detection limits in all blanks. Cd and Pb were present at significant concentrations only in the posttest blanks (about 10% of the controlled emission samples). Hg was present in the front half blanks (probably the filter) at about 8 µg. Pb emission rates dominate with about 30 mg/dscm (uncontrolled) and 0.1 mg/dscm (controlled). The control efficiency varies from 98% for cadmium to 99.8% for chromium, which is in general agreement with the relative volatilities of the metals.

As shown in Table 2-13, the ratio of the selected metals to total particulate mass increased or remained constant across the control device. The ratios increased by a factor of 2 for Cd and Hg, remained the same for As and Pb, and decreased for Cr.

## 2.5 METALS CONTENT OF PROCESS SAMPLES

Table 2-14 shows the metals content of the process samples collected. The selected metals are absent in the lime slurry with the exception of 4 µg/g of As. Cd and Hg were not detected in the bottom ash, and the other metals were present at levels of a few hundred micrograms per gram. Pb accounted for about half of the total. No bottom ash sample was collected for run 3.

At the cyclone ash hopper (immediately upstream of the uncontrolled emissions test location) and in the baghouse ash hopper, Pb was the predominant metal, as it was in the uncontrolled air emissions measurements. As, Cd, and Pb are more concentrated in both cyclone and baghouse ash than in the uncontrolled air emissions samples. Cr concentration values in the uncontrolled emissions fall between the Cr concentration values found in the cyclone and baghouse ash samples.

## TABLE 2-11. SUMMARY OF PARTICULATE EMISSIONS FOR THE MERC FACILITY

| Sampling location | Uncontrolled (spray dryer inlet) | | | | Controlled (fabric filter outlet) | | | |
|---|---|---|---|---|---|---|---|---|
| Run no. | 1 | 2 | 3 | | 1 | 2 | 3 | |
| Date | 12-09-87 | 12-10-87 | 12-12-87 | Average | 12-09-87 | 12-10-87 | 12-12-87 | Average |
| Sampling parameters[a] | | | | | | | | |
| Flue gas characteristics | | | | | | | | |
| Gas volume sampled (dscf) | 73.2 | 112 | 88.8 | - | 61.0 | 96.0 | 81.7 | - |
| Flue gas flow rate (dscfm) | 41,500 | 42,100 | 42,500 | 42,000 | 39,800 | 41,900 | 44,400 | 42,000 |
| Flue gas temperature (°F) | 374 | 367 | 398 | 380 | 270 | 271 | 273 | 271 |
| Moisture (percent by volume) | 15.1 | 15.2 | 16.8 | 15.7 | 16.8 | 16.3 | 14.6 | 15.9 |
| Sampling rate (percent isokinetic) | 99.2 | 100 | 102 | - | 106[c] | 106 | 105 | - |
| $CO_2$ (percent by volume, dry) | 10.9 | 11.0 | 11.3 | 11.1 | ND[c] | 10.9 | 11.3 | 11.0[c] |
| $O_2$ (percent by volume, dry) | 8.6 | 8.5 | 8.2 | 8.4 | ND[c] | 8.6 | 8.2 | 8.5[c] |
| Particulate results[b] | | | | | | | | |
| Front half catch | | | | | | | | |
| (Probe, cyclone, filter) | | | | | | | | |
| mg-mass | 14,000 | 19,000 | 19,000 | - | 34.3 | 80.4 | 96.9 | - |
| grains/dscf | 2.94 | 2.61 | 3.33 | 2.96 | 0.009 | 0.013 | 0.018 | 0.013 |
| grains/dscf (corrected to 12% $CO_2$) | 3.23 | 2.85 | 3.53 | 3.20 | 0.009[c] | 0.014 | 0.019 | 0.014 |
| mg/dscm | 6,730 | 5,990 | 7,630 | 6,780 | 19.9 | 29.6 | 41.9 | 30.5 |
| mg/dscm (corrected to 12% $CO_2$) | 7,410 | 6,540 | 8,100 | 7,350 | 21.9[c] | 32.6 | 44.5 | 33.0 |
| lb/h | 1,040 | 942 | 1,210 | 1,070 | 2.96 | 4.63 | 6.94 | 4.84 |
| kg/h | 474 | 428 | 550 | 484 | 1.34 | 2.10 | 3.15 | 2.20 |
| Removal efficiency (%) | | | | | 99.7 | 99.5 | 99.4 | 99.5 |

---

[a] Standard conditions are 68°F (20°C) and 1 atm (1.01325 × $10^5$ Pa).

[b] Results are adjusted for blanks.

[c] Not determined from actual diluent data (method 3 sampling train leaked); inlet results used here for run 1.

## TABLE 2-12. SPECIFIC METALS MASS EMISSION RATES FOR MERC (NORMALIZED TO 12% $CO_2$)

| Metal | Run 1 | | Run 2 | | Run 3 | | Average | |
|---|---|---|---|---|---|---|---|---|
| | ug/dscm | g/h | ug/dscm | g/h | ug/dscm | g/h | ug/dscm | g/h |
| **Uncontrolled** | | | | | | | | |
| Arsenic | 462 | 33 | 513 | 36 | 511 | 37 | 495 | 35 |
| Cadmium | 990 | 70 | 1,030 | 73 | 1,230 | 89 | 1,080 | 77 |
| Chromium | 2,300 | 162 | 2,600 | 185 | 3,110 | 225 | 2,670 | 191 |
| Lead | 25,700 | 1,810 | 26,700 | 1,900 | 27,400 | 1,980 | 26,600 | 1,900 |
| Mercury | 481 | 34 | 315 | 22 | 341 | 24 | 379 | 27 |
| **Controlled** | | | | | | | | |
| Arsenic | $7.53^b$ | $0.509^b$ | $6.79^b$ | $0.483^b$ | $4.78^b$ | $0.361^b$ | 6.37 | 0.451 |
| Cadmium | $11.7^b$ | $0.791^b$ | $10.2^b$ | $0.726^b$ | $14.8^b$ | $1.12^b$ | 12.2 | 0.879 |
| Chromium | $5.75^b$ | $0.389^b$ | $5.73^b$ | $0.408^b$ | $6.47^b$ | $0.488^b$ | 5.98 | 0.428 |
| Lead | 142 | 9.60 | 151 | 10.7 | 172 | 13.0 | 155 | 11.1 |
| Mercury | $< 2.03^a$ | $< 0.137^a$ | $6.00^b$ | $0.427^b$ | $7.77^b$ | $0.586^b$ | 6.89 | 0.506 |
| **Removal Efficiency** | | | | | | | | |
| | Run 1 | | Run 2 | | Run 3 | | Average | |
| Arsenic | 98.5 | | 98.7 | | 99.1 | | 98.7 | |
| Cadmium | 98.8 | | 99.0 | | 98.8 | | 98.9 | |
| Chromium | 99.7 | | 99.8 | | 99.8 | | 99.8 | |
| Lead | 99.4 | | 99.4 | | 99.4 | | 99.4 | |
| Mercury | $< 99.6^a$ | | 98.1 | | 97.7 | | 98.2 | |

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[a] Some fractions below detection limit. Reported value is maximum possible.

[b] All fractions below detection limit. Not included in averages.

TABLE 2-13. RATIO OF METALS TO PARTICULATE MASS FOR MERC (μg/g)[a]

| Metal | Run 1 | Run 2 | Run 3 | Average |
|---|---|---|---|---|
| | | Uncontrolled | | |
| As | 62.4 | 78.5 | 63.1 | 68.0 |
| Cd | 134 | 157 | 151 | 147 |
| Cr | 310 | 398 | 384 | 364 |
| Pb | 3,460 | 4,080 | 3380 | 3,640 |
| Hg | 65 | 48 | 42 | 52 |
| | | Controlled | | |
| As | 340[b] | 210[b] | 110[b] | 220 |
| Cd | 540[b] | 320[b] | 330[b] | 400 |
| Cr | 260[b] | 180[b] | 140[b] | 190 |
| Pb | 6510 | 4680 | 3860 | 5020 |
| Hg | < 390[c] | 190[b] | 170[b] | 180 |

[a] Ratios are calculated with total train results by AA for the metals and front half train results for the particulates. The ratio (μg/g) is calculated by dividing the concentration (μg) by the particulate loading (g).

[b] Some fractions below detection limit. Reported value is maximum possible.

[c] All fractions below detection limit. Not included in averages.

TABLE 2-14. METALS CONTENT OF PROCESS SAMPLES (μg/g)

| | Run 1 | Run 2 | Run 3 | Average |
|---|---|---|---|---|
| **Cyclone ash** | | | | |
| As | 32.2 | 32.7 | 38.9 | 34.6 |
| Cd | 30.7 | 35.2 | 38.1 | 34.7 |
| Cr | 383 | 438 | 424 | 415 |
| Pb | 2,100 | 2,090 | 2,070 | 2,087 |
| Hg | 15.3 | 5.00 | 13.4 | 11.2 |
| **Baghouse ash** | | | | |
| As | 47.6 | 47.2 | 53.6 | 49.5 |
| Cd | 129 | 80.1 | 77.4 | 95.5 |
| Cr | 152 | 159 | 167 | 159 |
| Pb | 2,770 | 1,290 | 2,130 | 2,063 |
| Hg | 80.2 | 34.0 | 29.4 | 47.9 |
| **Bottom ash** | | | | |
| As | 7.24 | 14.0 | b | 10.6 |
| Cd | < 1.50[a] | 2.73 | b | 2.73 |
| Cr | 169 | 312 | b | 241 |
| Pb | 417 | 585 | b | 501 |
| Hg | 0.0640 | 1.22 | b | 0.64 |
| **Lime slurry** | | | | |
| As | 4.25 | 2.20 | 4.19 | 3.55 |
| Cd | < 0.226[a] | < 0.231[a] | < 0.199[a] | < 0.219 |
| Cr | < 0.943[a] | < 0.960[a] | < 0.830[a] | < 0.911 |
| Pb | < 5.78[a] | < 5.88[a] | < 5.09[a] | < 5.58 |
| Hg | < 0.224[a] | < 0.216[a] | 0.419 | < 0.286 |

[a] Metal concentration below the indicated detection limit. Not included in averages.

[b] Bottom ash was not collected during run 3.

## 2.6 OTHER PROCESS SAMPLE ANALYSES

Table 2-15 shows the results of the analyses of general characteristics measured in the ash and lime slurry samples. The baghouse ash resistivity was also measured (Figure 2-5). Resistivity can be used to predict the performance of an electrostatic precipitator. Resistivity was measured by Southern Research Institute, Birmingham, Alabama, and the other analyses were performed by Galbraith Laboratories, Inc., Knoxville, Tennessee. The analytical laboratory reports are in Appendix I.

## 2.7 ACID GASES

Table 2-16 summarizes the results of the dry basis CEM measurements for $SO_2$, HCl, and $NO_x$ which are not corrected to 12% $CO_2$. Figures 2-6 through 2-8 show the time plots for $SO_2$, Figures 2-9 through 2-11 show the time plots for HCl, and Figure 2-12 shows the plots for $NO_x$. Detailed CEM data are presented in Appendix F. The acid gas results are difficult to assess because the process was on manual control instead of the designed automatic system. The sudden change in lime slurry feed during run 2 is reflected prominently in the $SO_2$ and HCl plots.

The $SO_2$ analyzer used at the spray dryer inlet was subjected to poisoning of the electrochemical cell with consequent loss of sensitivity during each run. The same type of analyzer located at the baghouse outlet was not affected. The drift of the $SO_2$ analyzer at the spray dryer inlet was not constant. Instead, it occurred in sudden steps, usually during the port changes. Therefore, only the initial calibration was used to calculate the results, and data are reported only until the first change in sensitivity.

Heavy alkaline dust loading at the spray dryer outlet affected HCl measurements during run 3. If dust builds up on the filter elements, the filter effectively becomes an HCl scrubber, which biases the readings. Although the Entropy test crew could not find any apparent lime coating after the test, the analyzer was showing the characteristic low readings and slow response time[2] which are associated with the sample system contamination of alkaline material.

Table 2-17 shows the molar ratio of actual to stoichiometric lime for each test. Stoichiometric lime is defined in Appendix A (Sample Calculations) as the quantity of lime needed to exactly neutralize the average HCl and $SO_2$ present. Since the peak concentrations of HCl and $SO_2$ are about twice the averages, the moderately low lime flow rates used for run 1 were too low to neutralize the acid gases during maxima.

## 2.8 OTHER GASES

Table 2-18 summarizes the results of CEM measurements for $O_2$, $CO_2$, CO, and THC (corrected to 12% $CO_2$). Figures 2-13 through 2-15 show the oxygen concentration plots for each run. Figures 2-16 through 2-18 show the $CO_2$ plots, Figure 2-19 shows CO plots, and Figure 2-20 shows the THC plot. Detailed CEM data are presented in Appendix F.

## TABLE 2-15. PROCESS SAMPLES--BULK CHARACTERISTICS

| | Run 1 | Run 2 | Run 3 | Average |
|---|---|---|---|---|
| Bottom ash | | | | |
| Carbon, % | 1.30 | 1.11 | None collected | 1.20 |
| Ash, % | 72.2 | 75.5 | None collected | 75.3 |
| Cyclone ash | | | | |
| Carbon, % | 1.06 | 0.89 | 1.60 | 1.18 |
| Ash, % | 98.3 | 98.3 | 95.8 | 97.5 |
| Baghouse ash | | | | |
| Carbon, % | 5.48 | 2.62 | 3.67 | 3.92 |
| Ash, % | 89.1 | 96.0 | 90.2 | 91.8 |
| Lime slurry | | | | |
| CaO, % | 11.8 | 9.58 | 12.3 | 11.2 |
| Solids, % | 20.6 | 18.3 | 22.1 | 20.4 |
| Specific gravity | 1.13 | 1.12 | 1.14 | 1.13 |

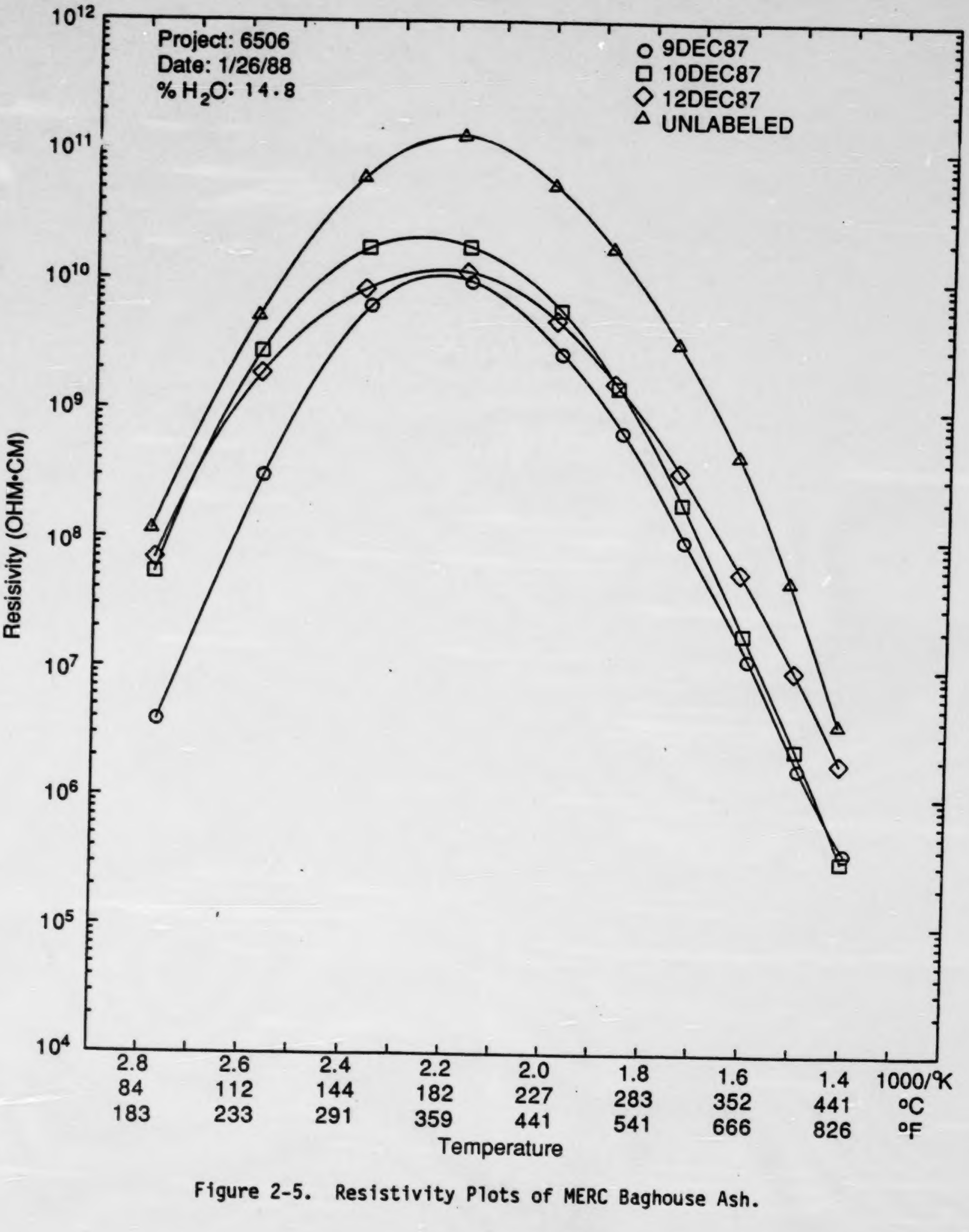


Figure 2-5. Resistivity Plots of MERC Baghouse Ash.

TABLE 2-16. CEM DATA SUMMARY--ACID GASES

| | | Average (ppm) | RSD[a] (%) |
|---|---|---|---|
| Run 1 | | | |
| $SO_2$ | Dryer inlet | 83.2 | 16.1 |
| | Baghouse outlet | 28.4 | 43.3 |
| | Removal efficiency | 66.0 | - |
| HCl | Dryer inlet | 478 | NA[d] |
| | Dryer outlet | 63 | NA |
| | Baghouse outlet | 9 | NA |
| | Removal efficiency | 98.2 | - |
| $NO_x$ | Baghouse outlet | 203 | 8.72 |
| Run 2[b] | | | |
| $SO_2$ | Dryer inlet | 76.9 | 11.3 |
| | Baghouse outlet | 21.2 | 45.6 |
| | Removal efficiency | 72.3 | - |
| HCl | Dryer inlet | 566 | NA |
| | Dryer outlet | 8 | NA |
| | Baghouse outlet | 4 | NA |
| | Removal efficiency | 99.3 | - |
| $NO_x$ | Baghouse outlet | 206 | 8.25 |
| Run 3 | | | |
| $SO_2$ | Dryer inlet | 115 | 20.3 |
| | Baghouse outlet | 12.0 | 18.6 |
| | Removal efficiency | 89.6 | - |
| HCl | Dryer inlet | 540 | NA |
| | Dryer outlet[c] | 1 | NA |
| | Baghouse outlet | 3 | NA |
| | Removal efficiency | 99.4 | - |
| $NO_x$ | Baghouse outlet | 210 | 8.76 |
| Average of 3 runs | | | |
| $SO_2$ | Dryer inlet | 91.8 | - |
| | Baghouse outlet | 20.5 | - |
| | Removal efficiency | 76.0 | - |
| HCl | Dryer inlet | 528 | - |
| | Dryer outlet | 24 | - |
| | Baghouse outlet | 5 | - |
| | Removal efficiency | 99 | - |
| $NO_x$ | Baghouse outlet | 206 | - |

[a] RSD (relative standard deviation) = (100 x standard deviation) ÷ mean.

[b] Spray dryer lime slurry flow rate was increased by 100% at about 13:45 during run 2.

[c] HCl results at the dryer outlet are questionable for run 3.

[d] NA = Data is not available for HCl, which is contained in a separate report by Entropy Environmentalists Inc. (Ref. 2)

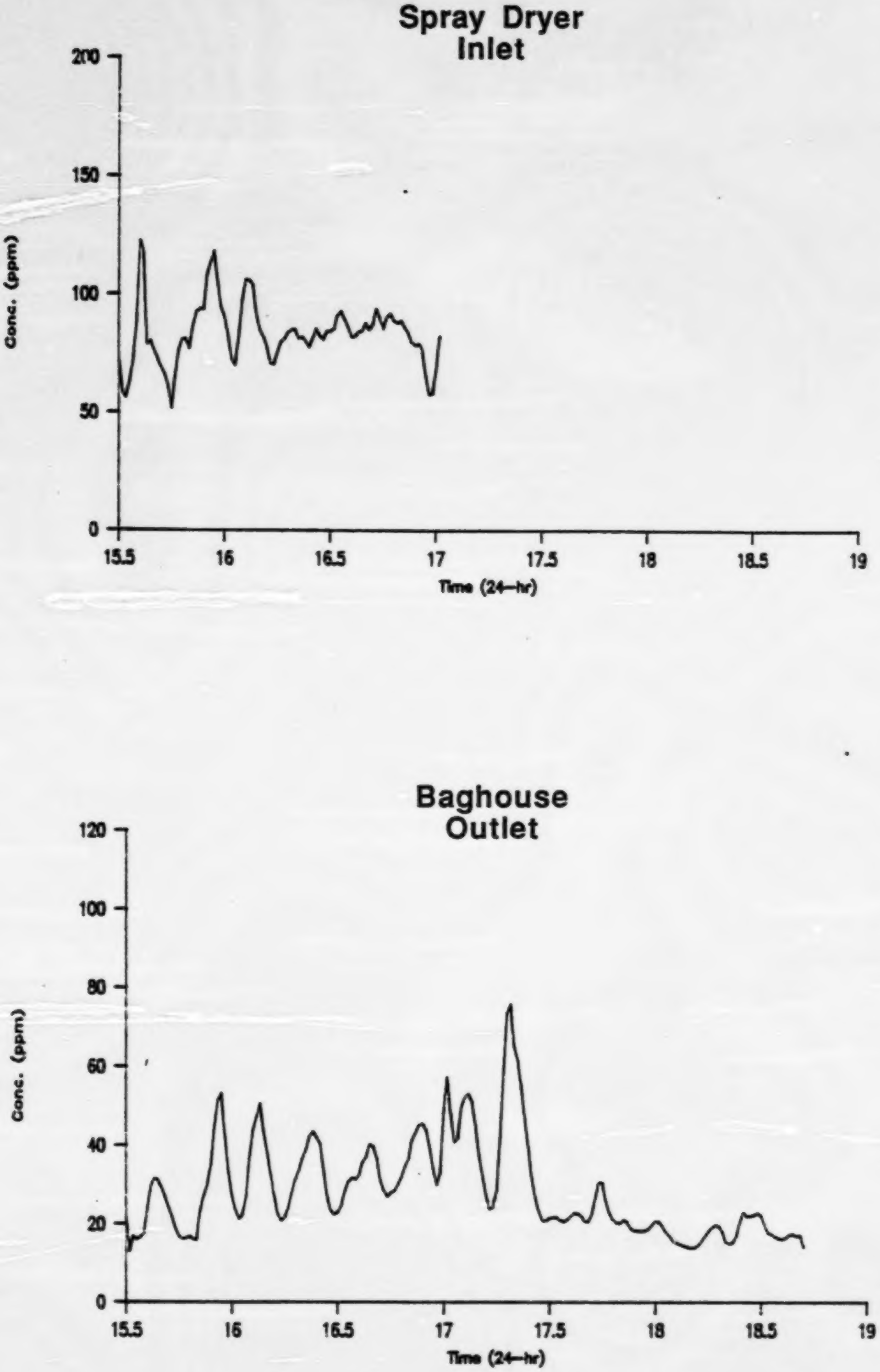
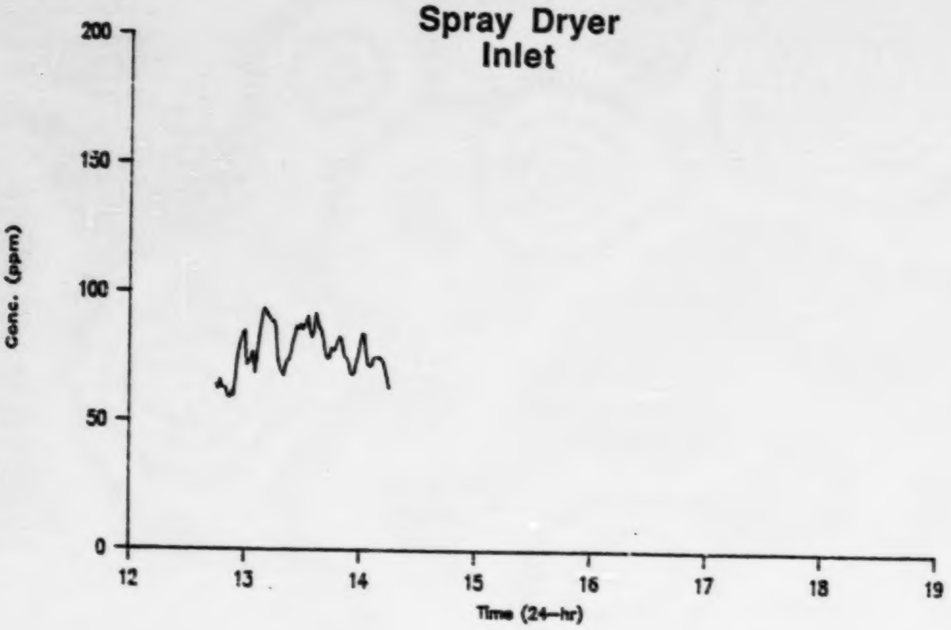


Figure 2-6. Run 1 $SO_2$ Concentrations.



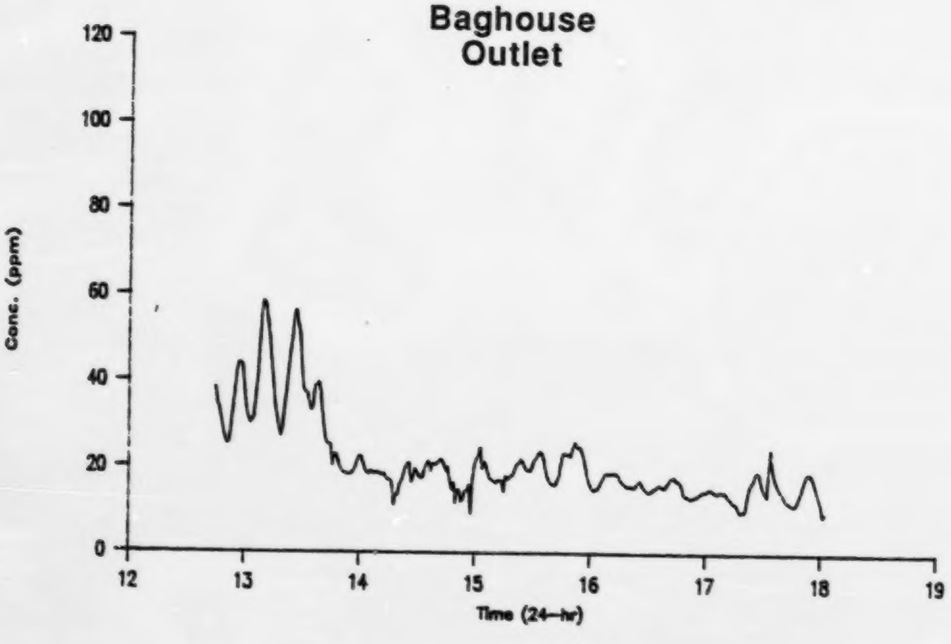


Figure 2-7. Run 2 $SO_2$ Concentrations.

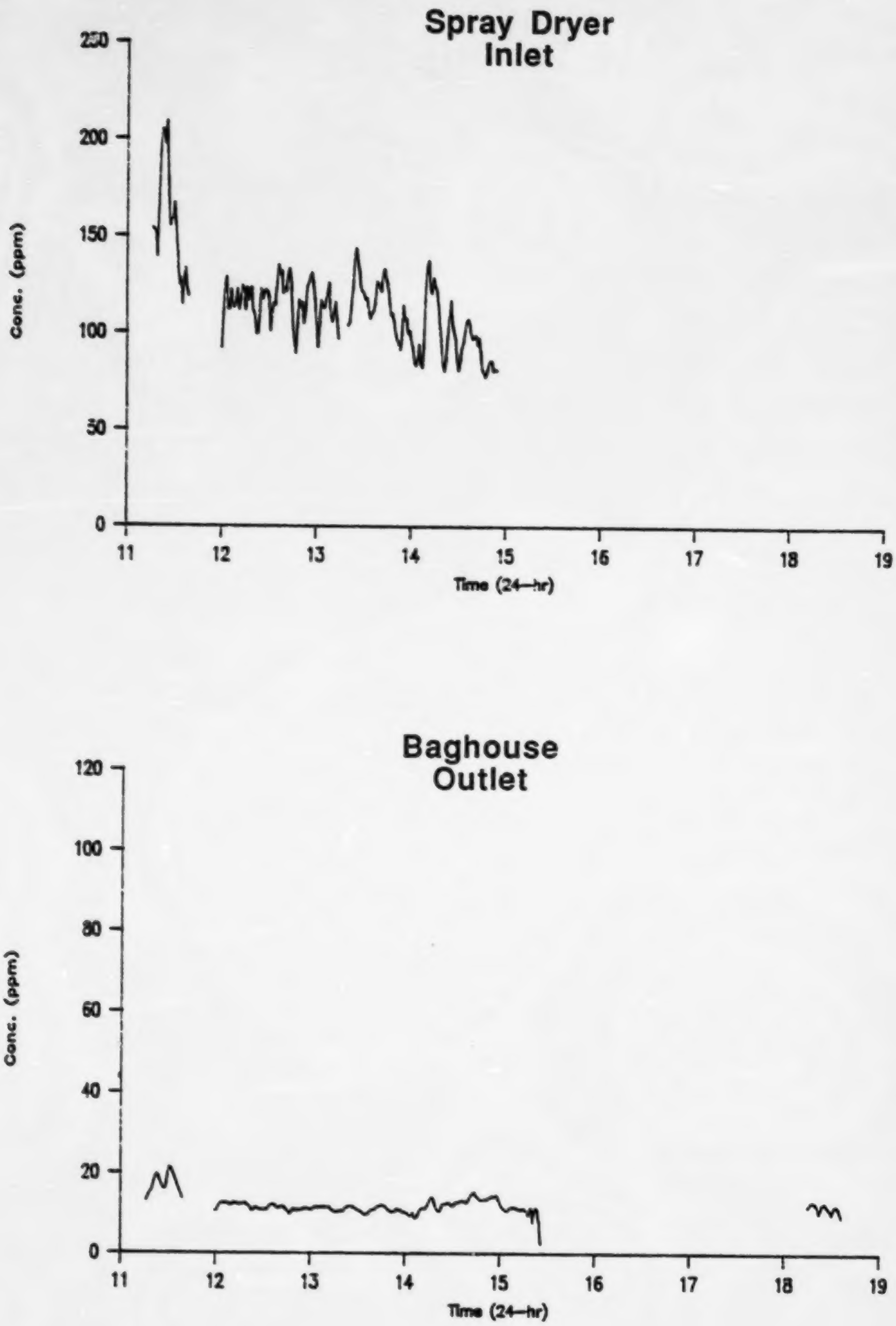


Figure 2-8. Run 3 $SO_2$ Concentrations.

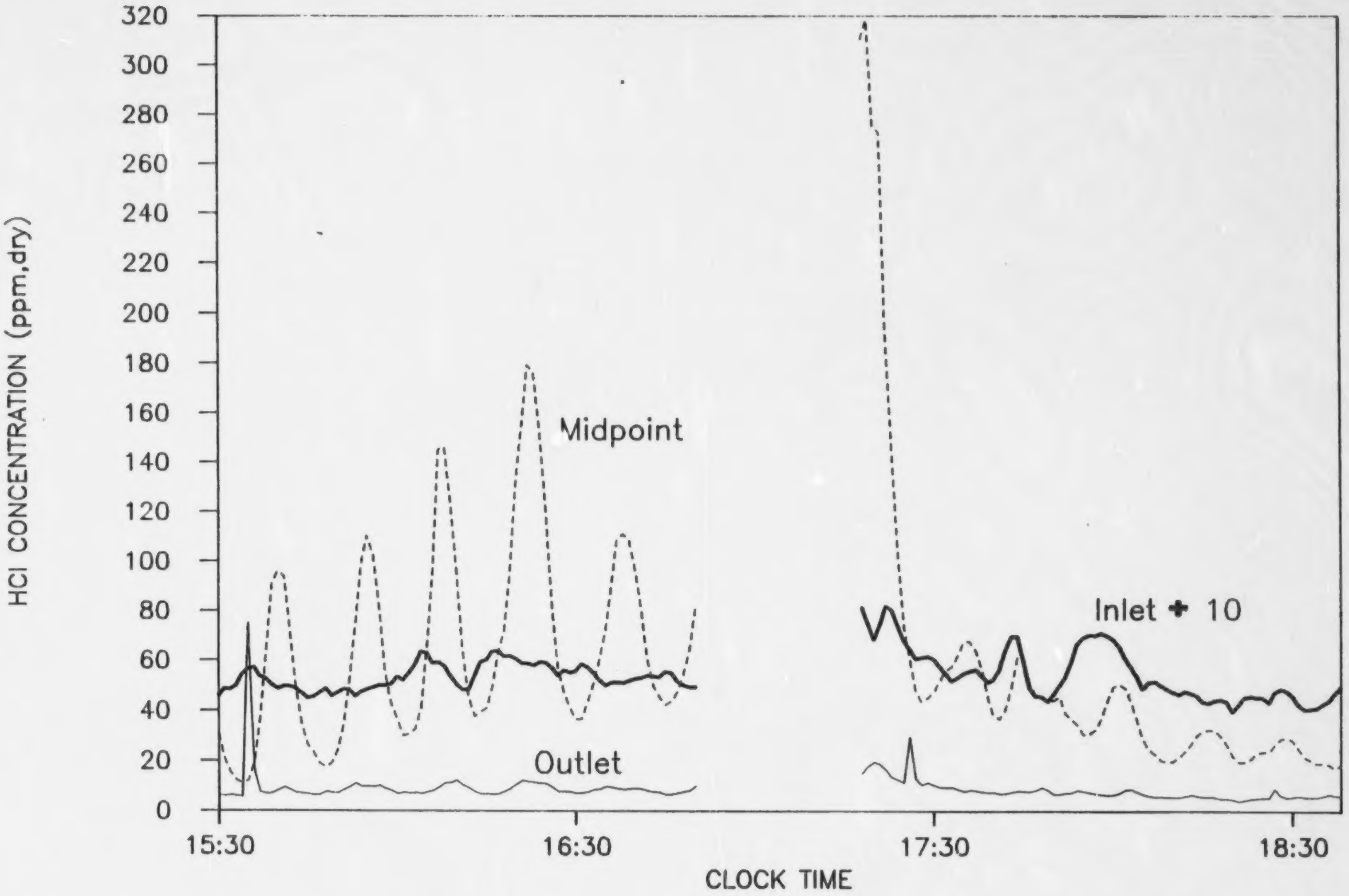


Figure 2-9. Run 1 HCl Concentrations.

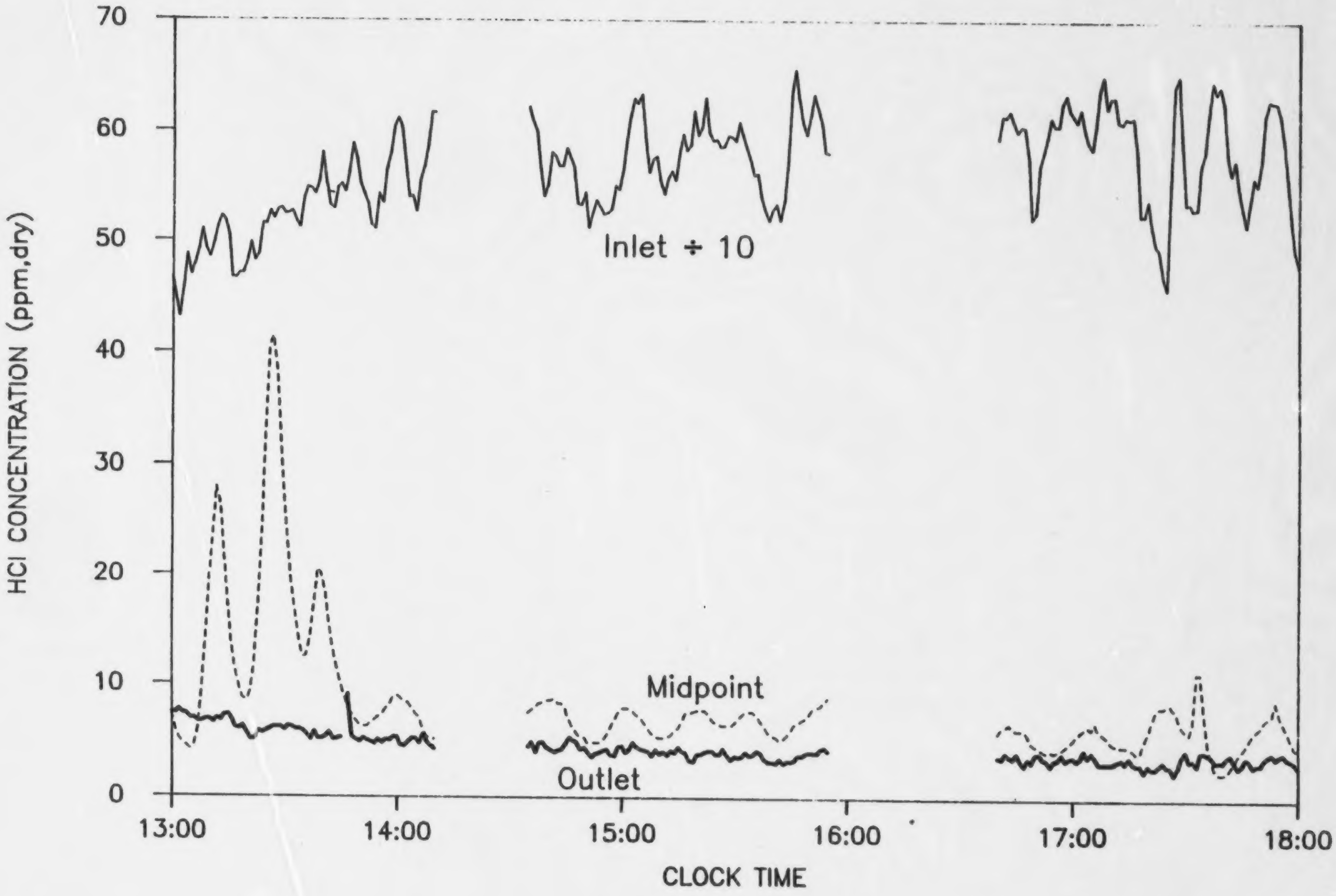


Figure 2-10. Run 2 HCl Concentrations.

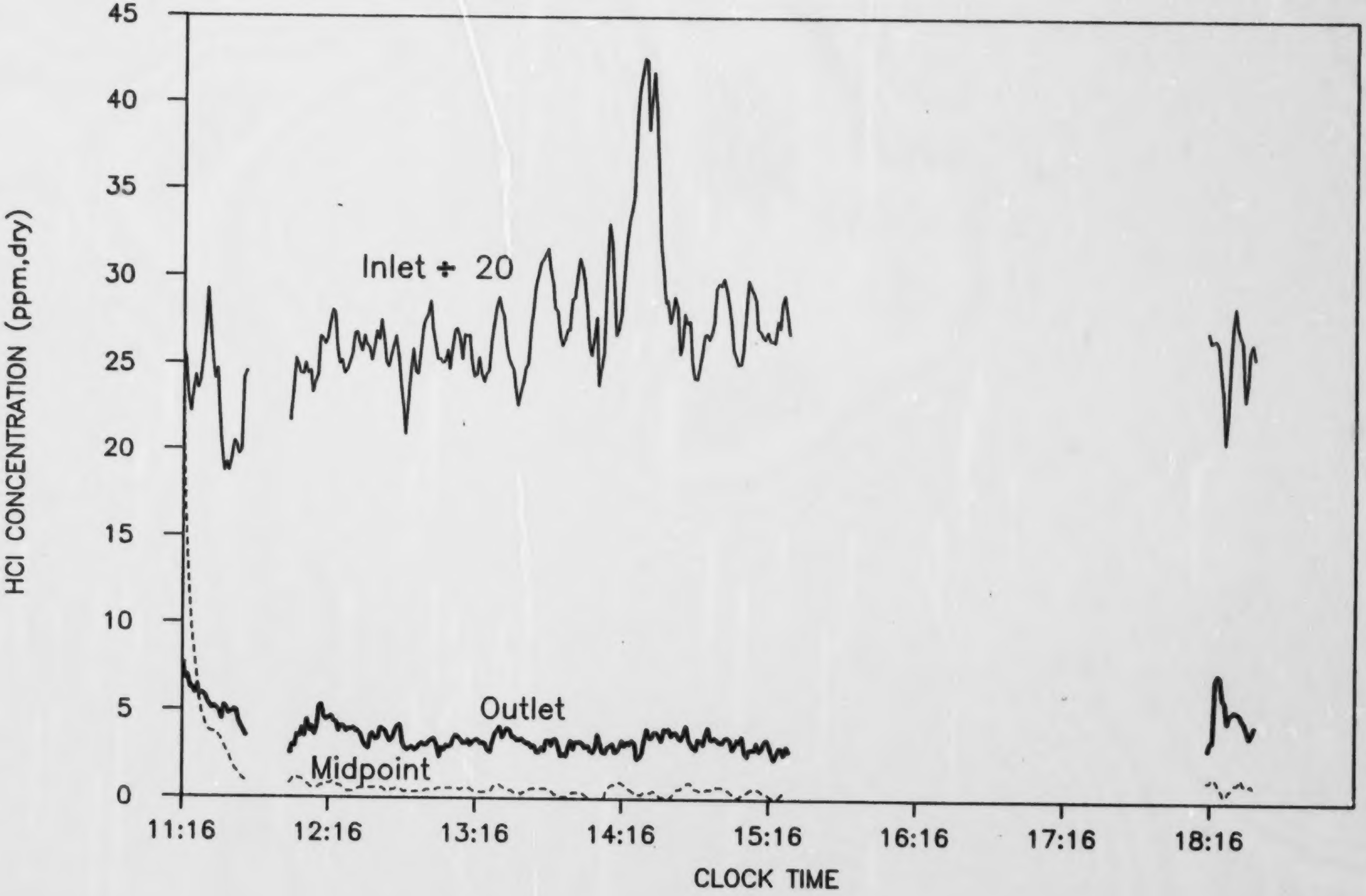


Figure 2-11. Run 3 HCl Concentrations.

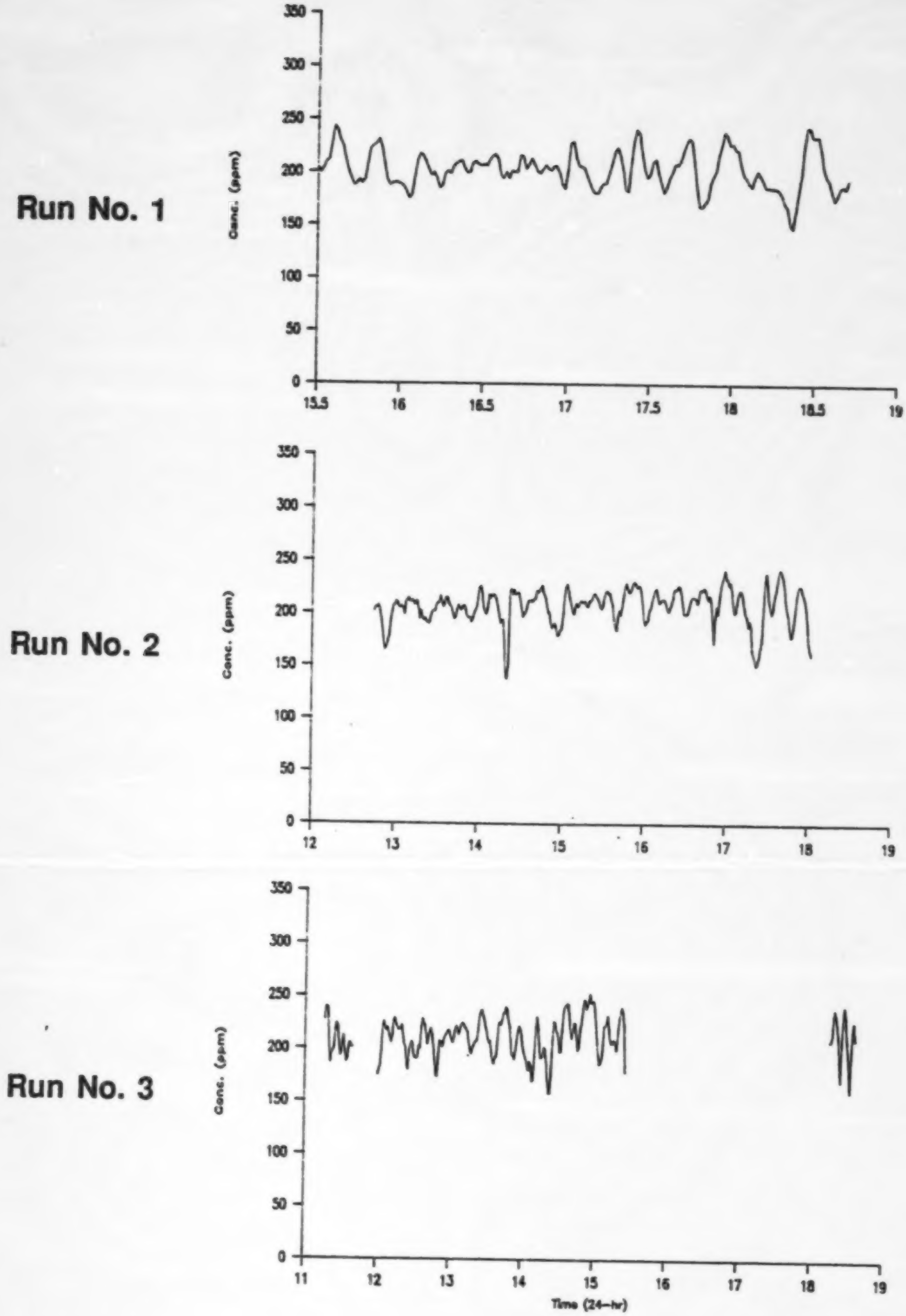


Figure 2-12. $NO_x$ Concentrations at the Baghouse Outlet.

TABLE 2-17. MOLAR RATIO OF ACTUAL LIME TO STOICHIOMETRIC LIME FOR HCl AND $SO_2$

| Run | $\frac{\text{Actual lime}}{\text{Stoichiometric lime}}$ for HCl | $\frac{\text{Actual lime}}{\text{Stoichiometric lime}}$ for HCl and $SO_2$ |
|---|---|---|
| 1 | 2.27 | 1.68 |
| 2 | 3.49 | 2.74 |
| 3 | 5.52 | 3.87 |
| Average | 3.76 | 2.76 |

TABLE 2-18. CEM DATA SUMMARY—OTHER GASES

| | | Average | RSD[a] (%) |
|---|---|---|---|
| Run 1[b] | | | |
| $O_2$, % | Dryer inlet | 7.9 | 14.8 |
| | Dryer outlet | 7.4 | 14.9 |
| | Baghouse outlet | 8.0 | 14.3 |
| $CO_2$, % | Dryer inlet | 11.6 | 8.45 |
| | Dryer outlet | 11.5 | 6.78 |
| | Baghouse outlet | 11.6 | 8.71 |
| CO, ppm | Dryer inlet | 62.8 | 36.1 |
| Run 2[b] | | | |
| $O_2$, % | Dryer inlet | 8.5 | 10.6 |
| | Dryer outlet | 7.9 | 13.7 |
| | Baghouse outlet | 8.4 | 12.4 |
| $CO_2$, % | Dryer inlet | 11.2 | 7.29 |
| | Dryer outlet | 11.7 | 2.82 |
| | Baghouse outlet | 11.1 | 8.47 |
| CO, ppm | Dryer inlet | 68.5 | 17.3 |
| Run 3 | | | |
| $O_2$, % | Dryer inlet | 8.4 | 13.3 |
| | Dryer outlet | 7.8 | 15.5 |
| | Baghouse outlet | 8.6 | 15.4 |
| $CO_2$, % | Dryer inlet | 11.2 | 12.0 |
| | Dryer outlet | 11.7 | 3.42 |
| | Baghouse outlet | 11.3 | 10.8 |
| CO, ppm | Dryer inlet | 89.9 | 55.9 |
| THC[a], ppm | Dryer inlet | 1.14 | 86.0 |

[a] RSD (relative standard deviation) = (100 × standard deviation) ÷ mean.

[b] The total hydrocarbon analyzer was not functioning properly for runs 1 and 2 and had span drift during run 3.

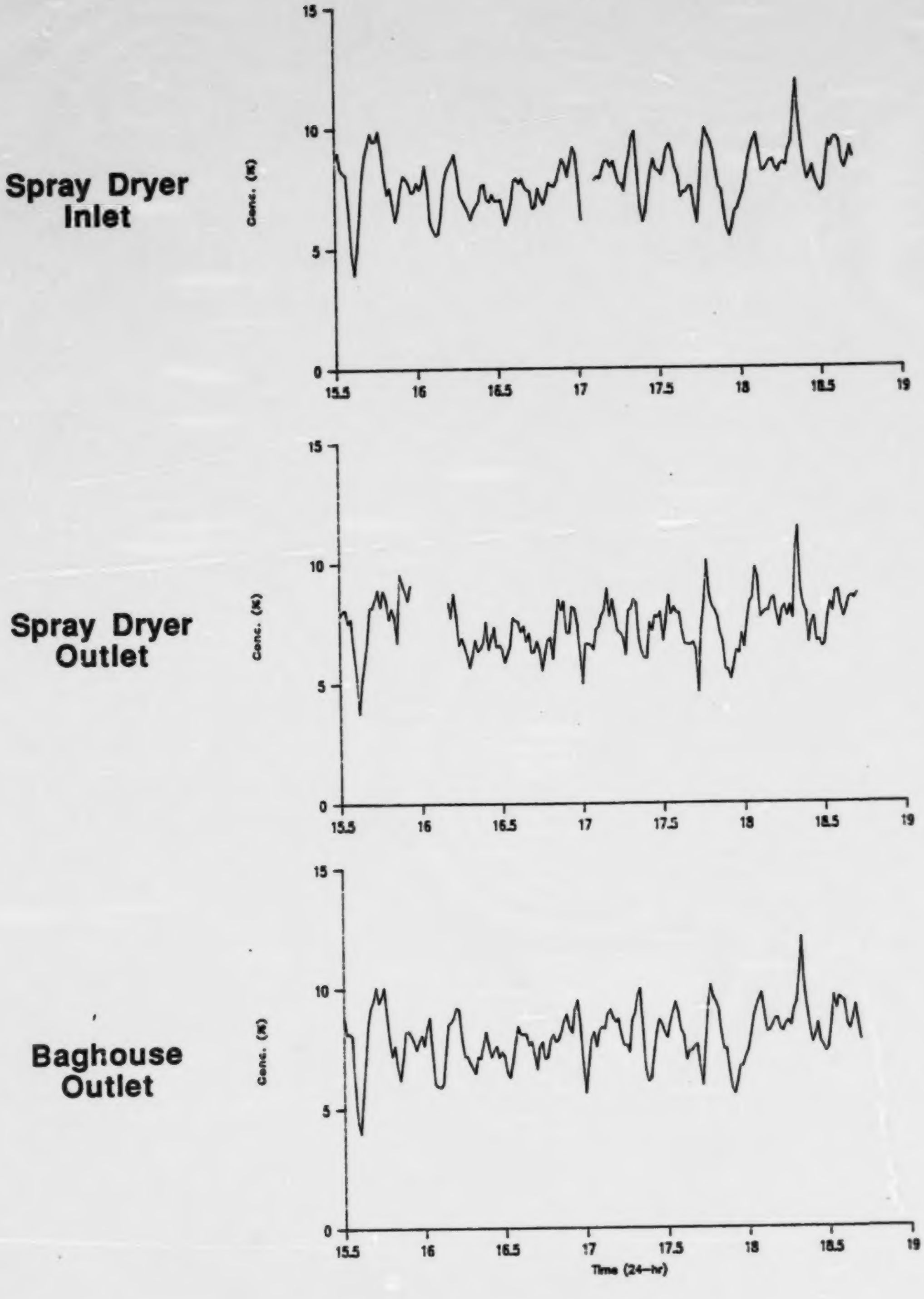


Figure 2-13. Run 1 Oxygen Concentrations.

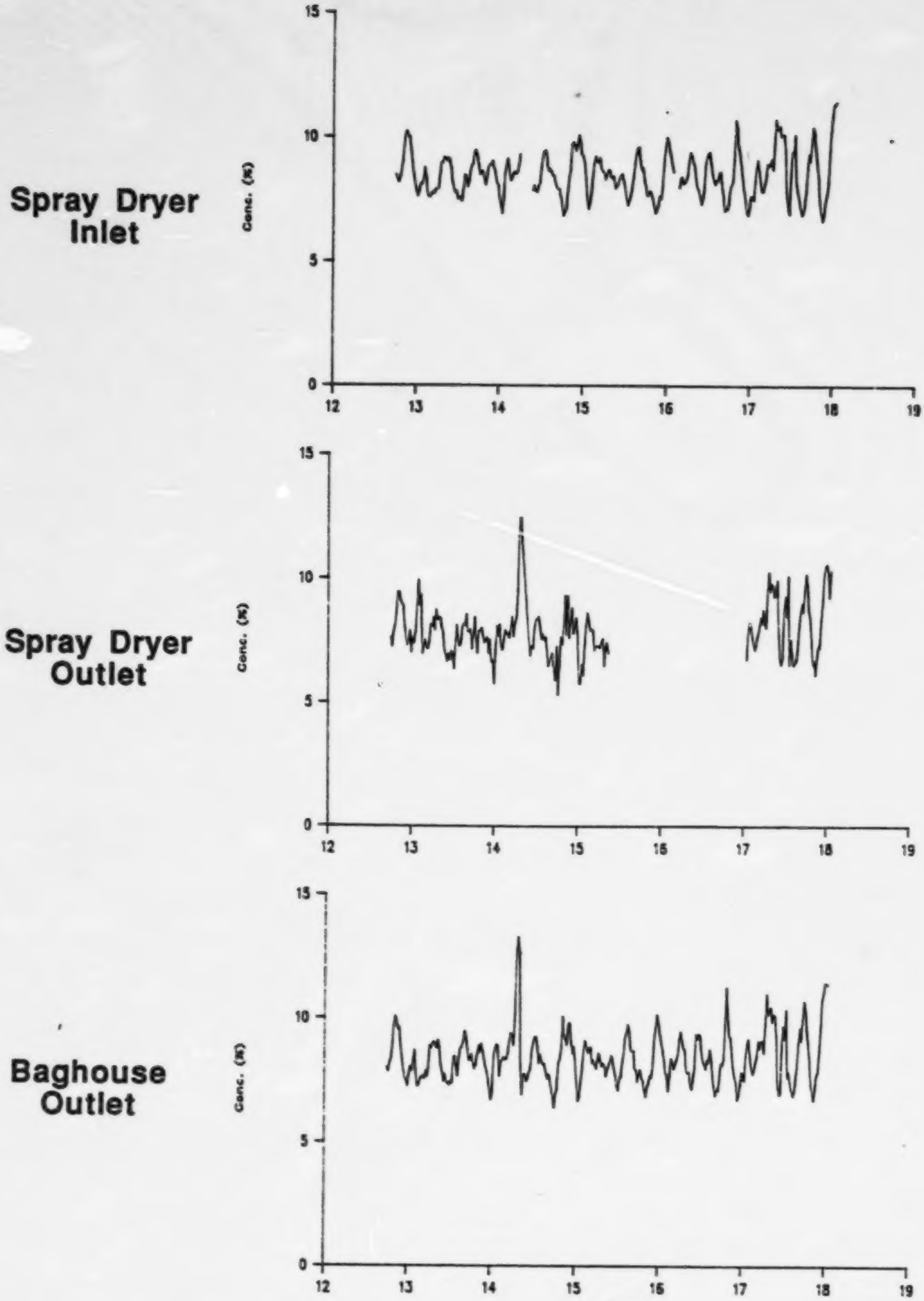


Figure 2-14. Run 2 Oxygen Concentrations.

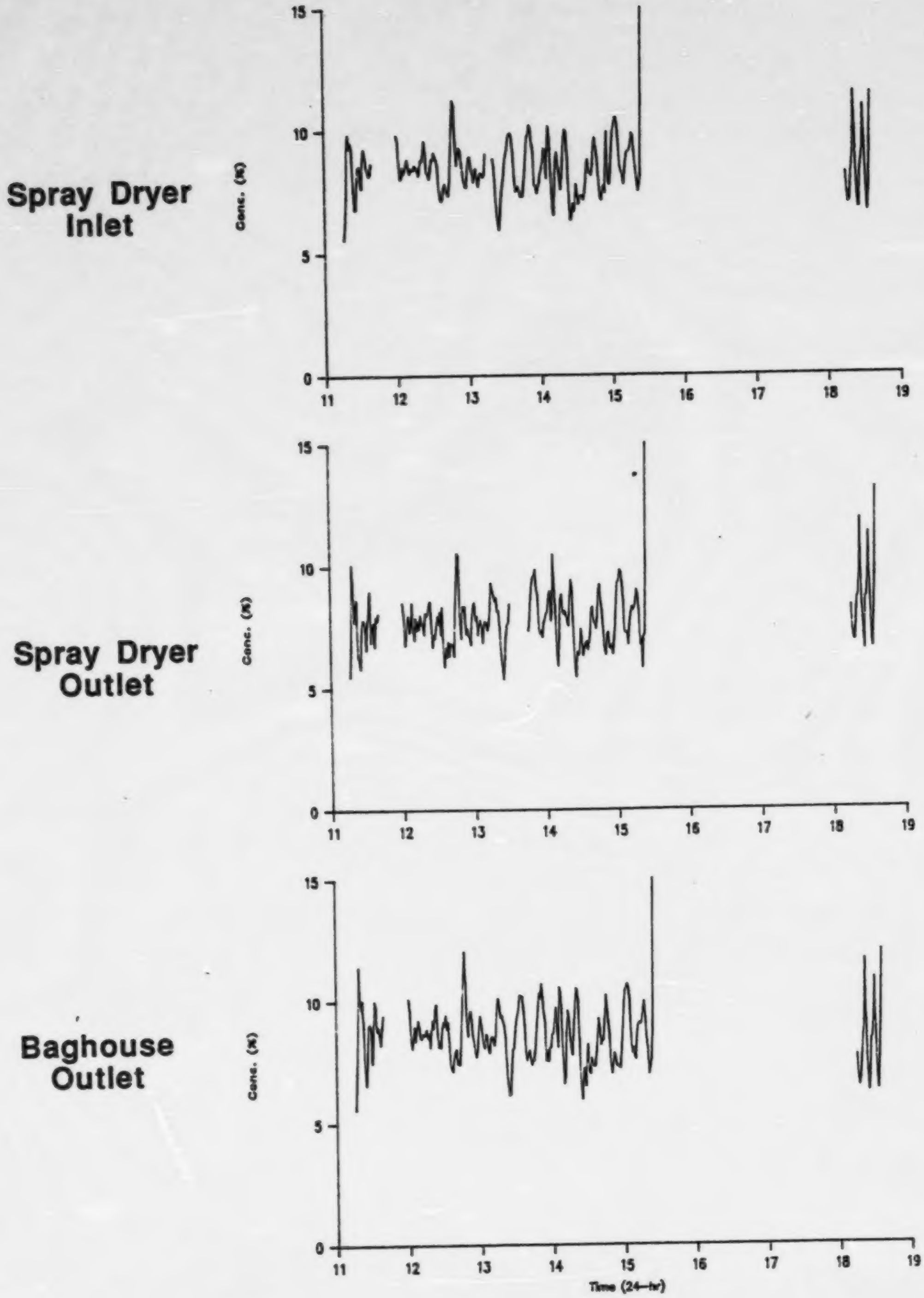


Figure 2-15. Run 3 Oxygen Concentrations.

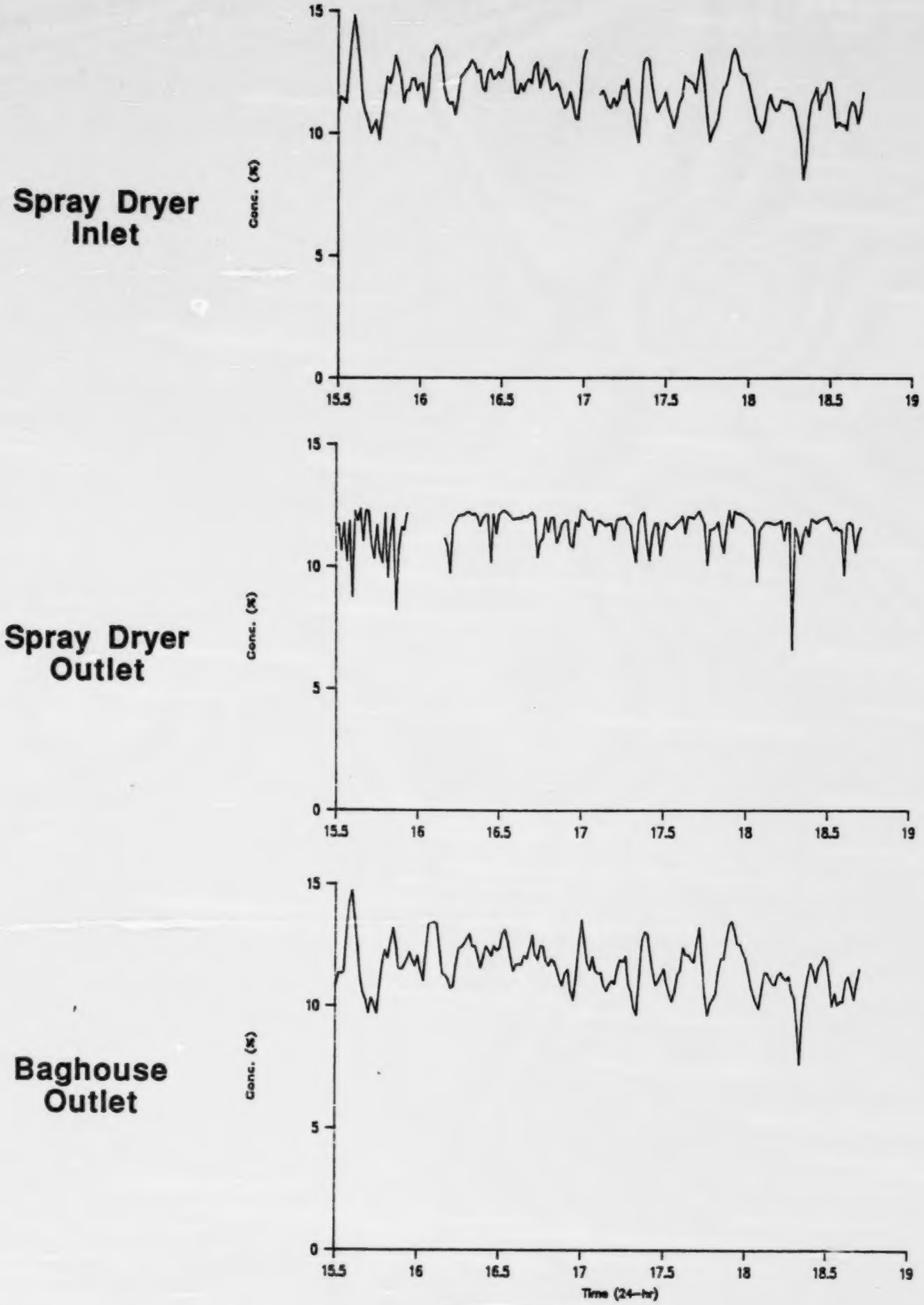


Figure 2-16. Run 1 $CO_2$ Concentrations.

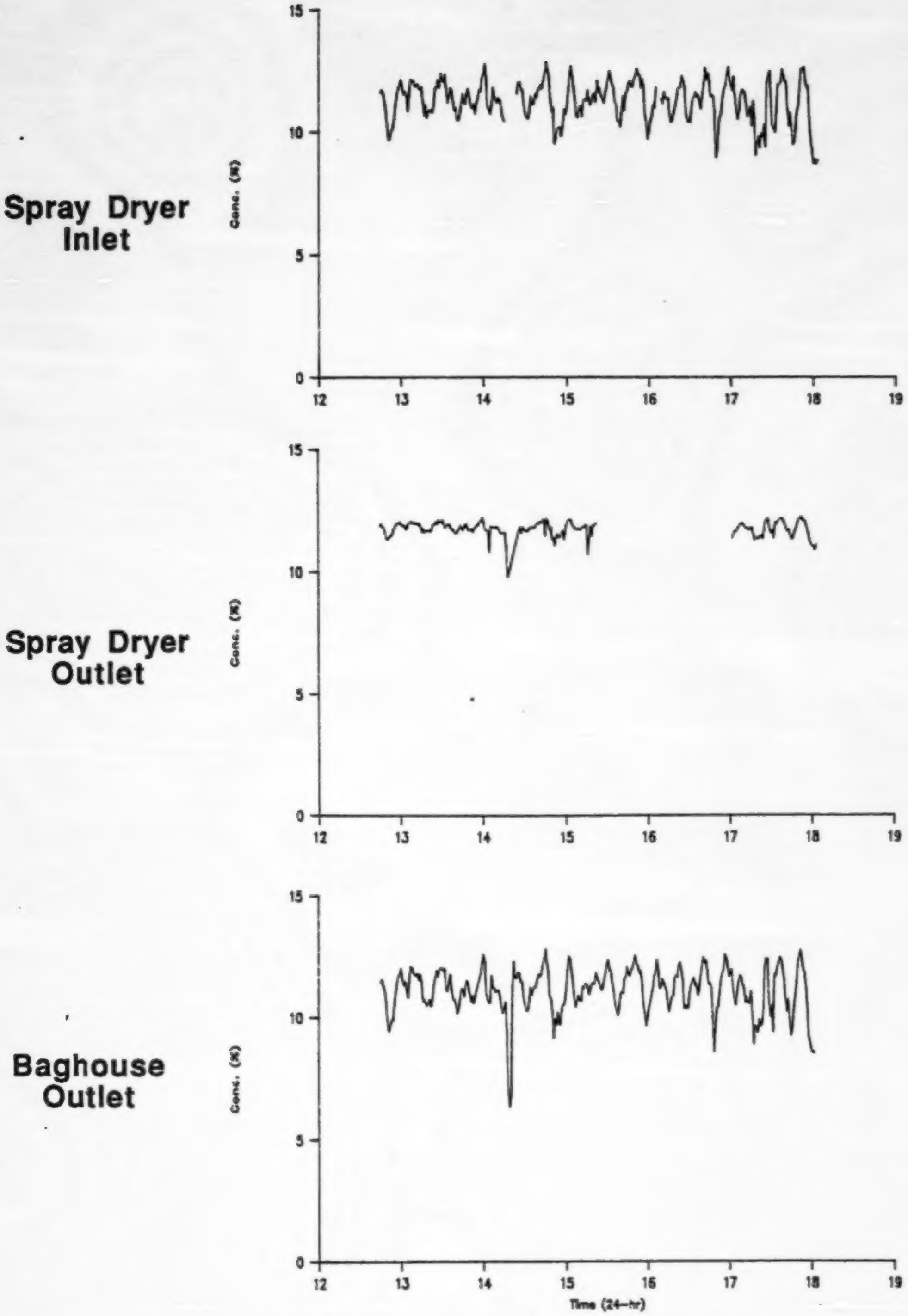
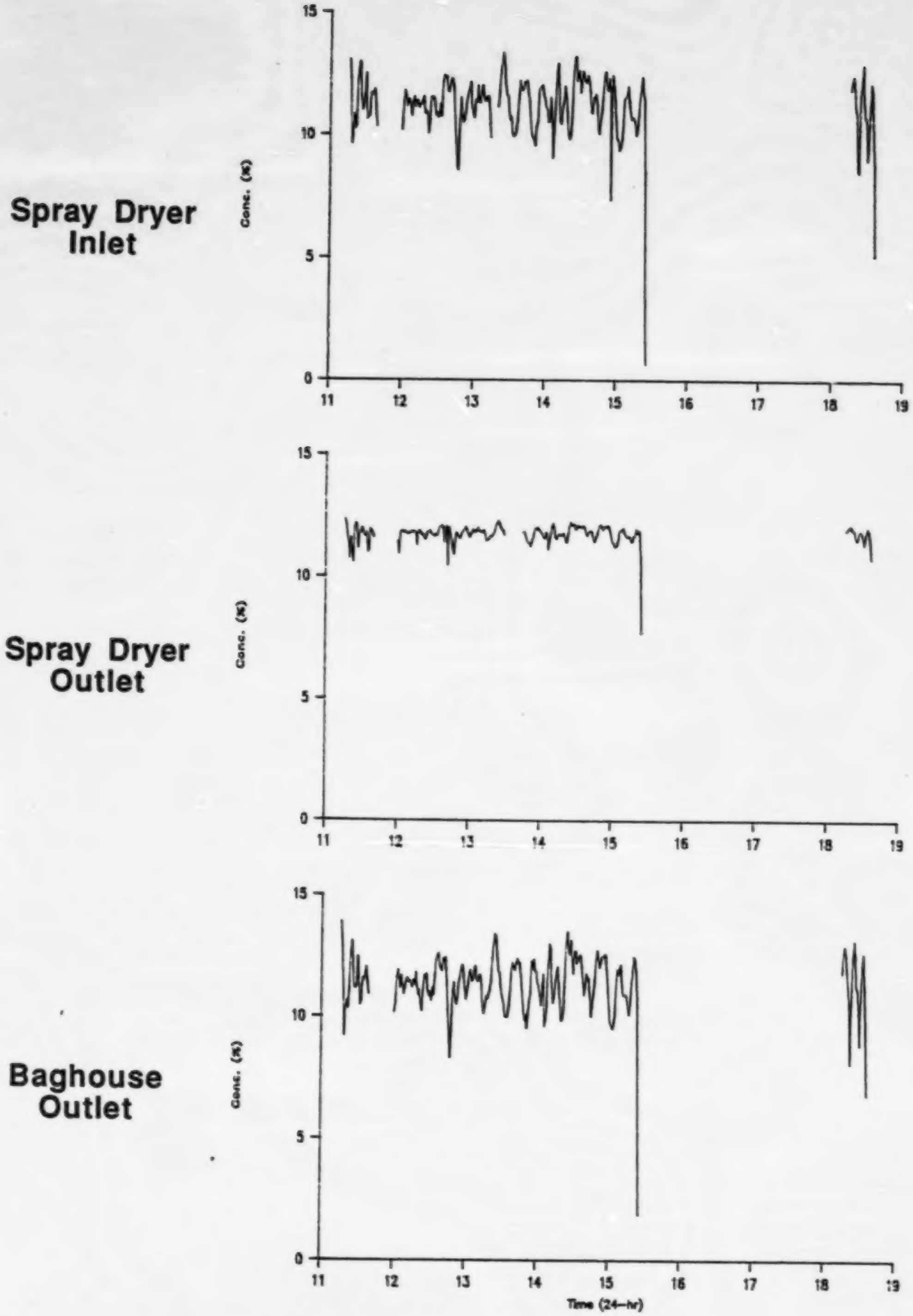


Figure 2-17. Run 2 $CO_2$ Concentrations.



Spray Dryer Inlet

Spray Dryer Outlet

Baghouse Outlet

Figure 2-18. Run 3 $CO_2$ Concentrations.

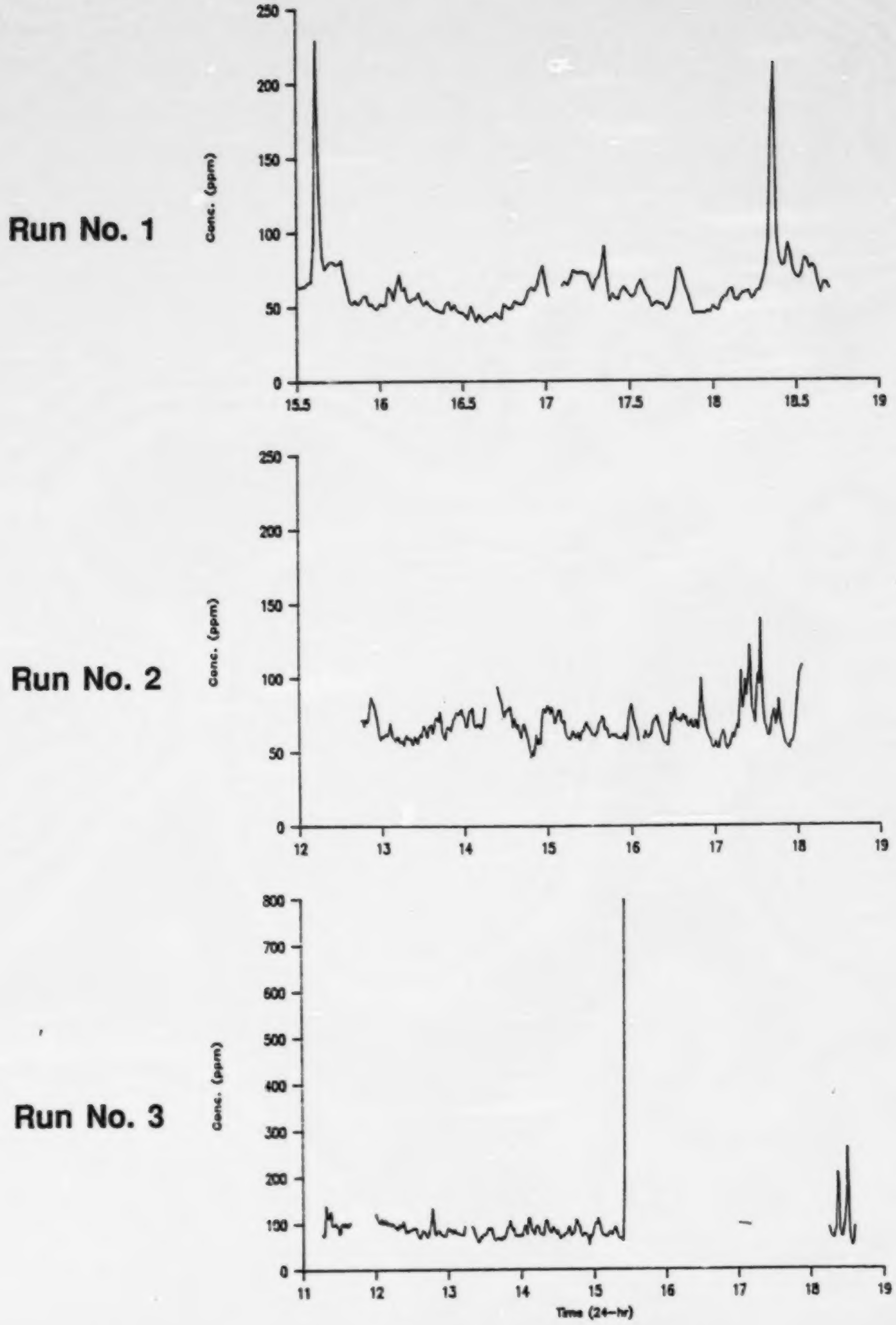


Figure 2-19. CO Concentrations at the Spray Dryer Outlet.

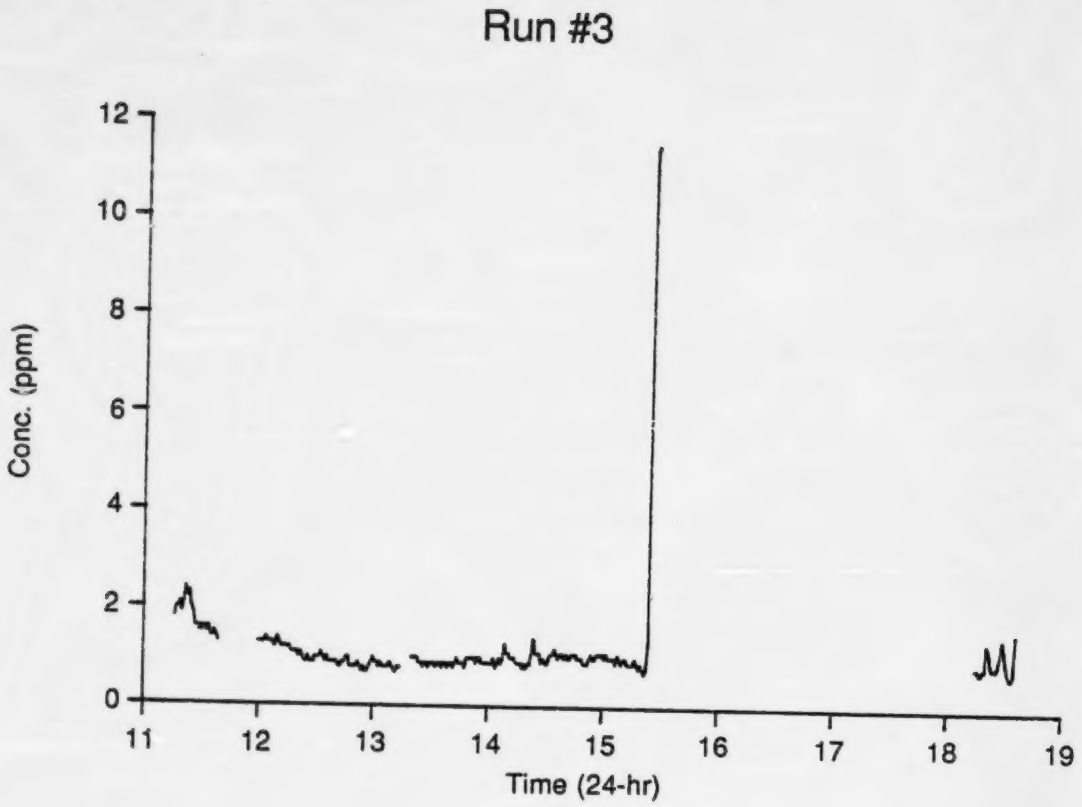


Figure 2-20. THC Concentrations at the Spray Dryer Inlet.

The oxygen and $CO_2$ results indicate that no significant leakage, dilution, or reaction of $CO_2$ occurred across the control devices. The $CO_2$ analyzer at the spray dryer outlet shows fewer excursions than the other analyzers because of slower response time for this instrument.

The CO measurements indicated that the unit was experiencing periodic combustion disturbances as evidenced by a number of CO transients which exceeded 200 ppm. It is expected that the CO transients were related to temporary combustion upsets caused by nonuniform refuse feed conditions. This could account for the moderately elevated emissions of PCDD/PCDF measured upstream of the spray dryer.

## 2.9 CONCLUSIONS AND RECOMMENDATIONS

Based on the results obtained during this project, the following conclusions are made:

- Removal efficiency across the spray dryer/fabric filter was about 99.5% for dioxins, furans, and particulates.
- The PCDF levels were about twice as large at the PCDD levels for both controlled and uncontrolled emission values.
- No significant change occurred across the control devices for the molar distributions of the tetra- through octa-CDF and CDD.
- Metals (As, Cd, Cr, Pb, and Hg) removal efficiencies varied from 98.2% for Hg to 99.8% for Cr.
- Concentrations of the five selected metals measured in the ash samples were in general agreement with the concentrations found in the stack samples.
- Removal efficiency for $SO_2$ varied from 66% in run 1 to 90% in run 3, in direct relation to the amount of slaked lime fed to spray dry adsorber.
- Control efficiency for HCl varied from 98% in run 1 to 99% in run 3.
- No air dilution or absorption of $CO_2$ occurred across the control devices.

The following recommendations are suggested for further study of this type of facility:

- Data should be obtained for the performance of the automatic lime control system.
- The effect of combustion conditions on the emission of PCDD/PCDF, CO, $NO_x$, and other pollutants should be investigated.

# SECTION 3.0

# PROCESS DESCRIPTION AND OPERATION DURING TEST PROGRAM

This section contains a description of the MERC Waste-to-Energy facility located in Biddeford, Maine. This section also summarizes the operation of the facility and the key operating parameters that were measured during the test program.

## 3.1 FACILITY DESCRIPTION

The MERC facility consists of two identical combustion process lines with emission control devices that exhaust to a common stack. The combustion process line is illustrated in Figure 3-1. Refuse-derived fuel (RDF) enters the combustor and is fired with preheated combustion air. Auxiliary fuel (natural gas or fuel oil) can be used during startup, shutdown, or for load stabilization. The combustion gases pass through the superheater, economizer, and combustion air preheater heat recovery sections. The combustion gases then pass through a cyclone to remove large particulate, an alkaline spray dryer to control acid gas emissions and lower flue gas temperature, and a fabric filter to reduce particulate emissions. The flue gas then exhausts to the atmosphere through a 244-ft high stack which is common to both units.

The MERC facility is rated at 23 mg/h (600 tons/day) of RDF. The facility is owned by KTI Holdings, Inc., and was designed and built by General Electric Environmental Services Company. Each unit can generate 47,628 kg/h (105,000 lb/h) of steam at a temperature of 760°F and pressure of 675 psig (superheated). The steam from the boilers is supplied to a steam turbine which generates up to 22 MW of electricity. The electricity is sold to Central Maine Power.

### 3.1.1. Preparation of Refuse-Derived Fuel

At the MERC facility, preparation of RDF follows the scheme shown in Figure 3-2. Solid waste from local municipalities is received in packer trucks and transfer trailers and unloaded on the tipping floor, which is enclosed. The waste is visually inspected, and potentially explosive or hazardous items are removed. Oversized waste is removed and sent to a shear shredder. The sorted waste is reduced in size by a flail mill and is combined with the end product from the shear shredder. Then a magnetic separator removes ferrous metal for reclamation. A trommel screen separates nonprocessible wastes, and the remaining refuse is shredded to a nominal top size of 10 cm (4 in.) by the secondary shredder. At this point, the waste has become RDF. MERC estimates that 23 Mg/h (607 tons/day) of solid waste is processed to produce 19 Mg/h (500 tons/day) of RDF.

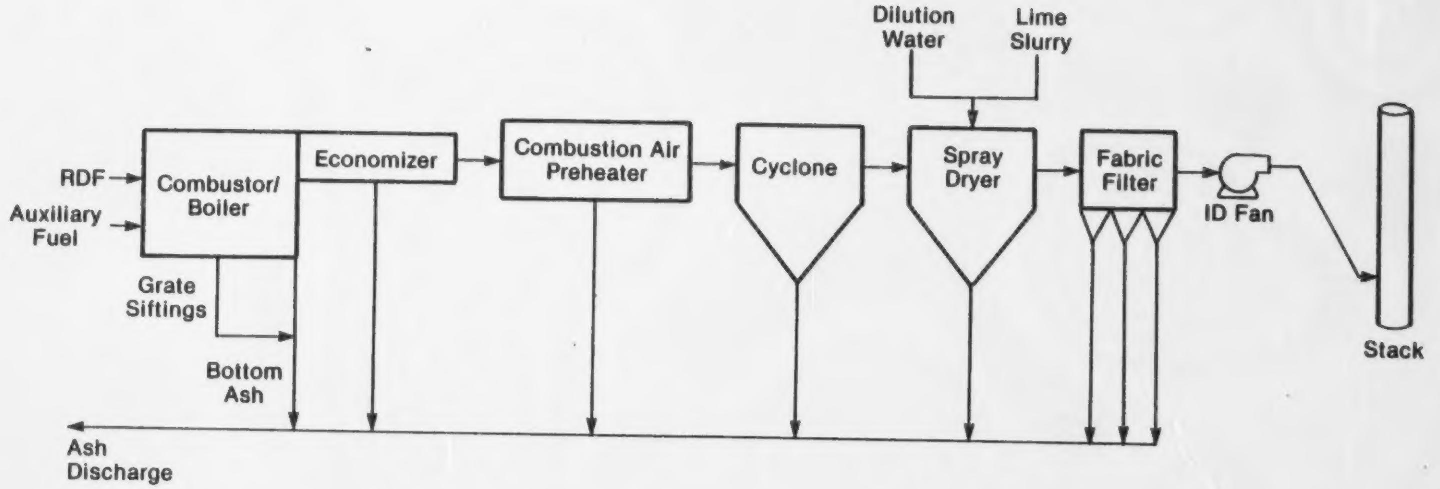

Dilution Water
Lime Slurry
RDF
Auxiliary Fuel
Combustor/ Boiler
Economizer
Combustion Air Preheater
Cyclone
Spray Dryer
Fabric Filter
ID Fan
Stack
Grate Siftings
Bottom Ash
Ash Discharge

Figure 3-1. Combustion Process Line at the MERC Facility.

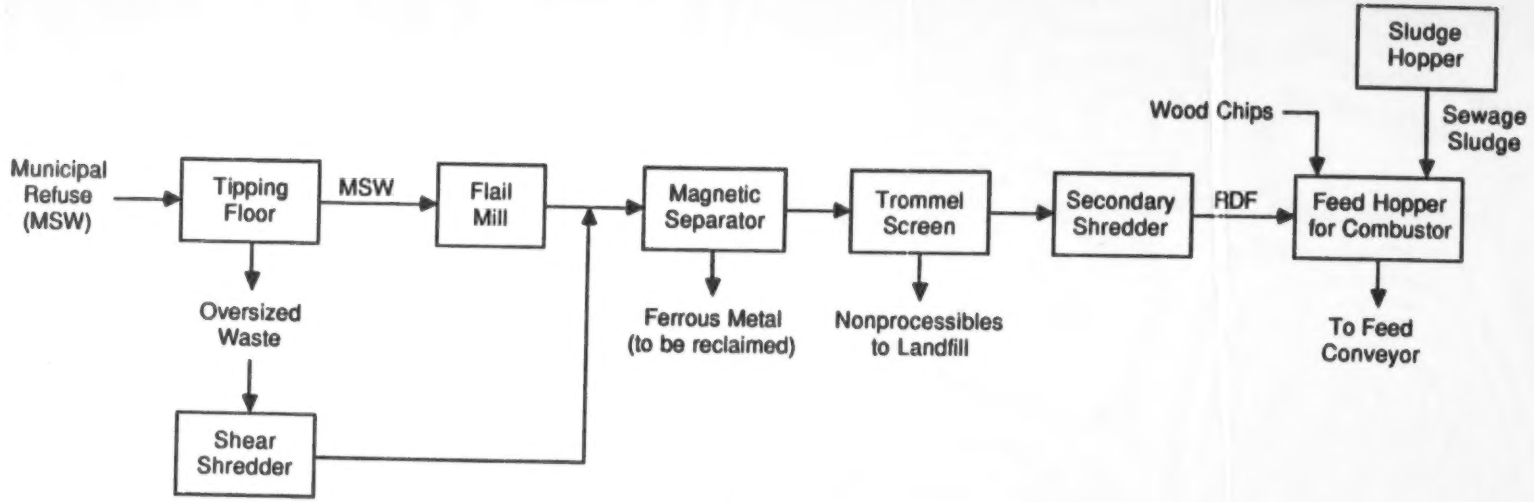

Municipal Refuse (MSW)
Tipping Floor
MSW
Flail Mill
Oversized Waste
Shear Shredder
Magnetic Separator
Ferrous Metal (to be reclaimed)
Trommel Screen
Nonprocessibles to Landfill
Secondary Shredder
RDF
Wood Chips
Sludge Hopper
Sewage Sludge
Feed Hopper for Combustor
To Feed Conveyor

Figure 3-2. Preparation of Refuse-Derived Fuel at the MERC Facility.

As the RDF enters the combustor feed hopper, wood chips or sewage sludge may be added, if desired. To date, only wood chips have been used. Sewage sludge can be received into a separate hopper which is enclosed by a hydraulically operated steel cover. The sewage sludge has a design moisture content between 12% and 21% and a design feed rate of 0.833 $yd^3/h$. This amount of sludge, as a percentage of the total fuel volume, has an insignificant effect on the boiler's firing rate. The fuel, whether RDF or RDF mixed with wood chips and/or sewage sludge, is metered from the hopper by dual feeders to the stoker.

### 3.1.2 Combustion Air

Air from the tipping floor area and boiler penthouse is withdrawn by a forced-draft (FD) fan to supply the air heater section of the heat recovery system. The preheated combustion air is split to supply the natural gas burners, overfire air ports, and undergrate air. The combustion air scheme is shown in Figure 3-3. The slightly negative pressure in the tipping floor area ensures a continuous movement of air through the processing building preventing excessive accumulation of odors from the solid waste.

### 3.1.3 Combustor and Boiler

The combustion system consists of a Detroit stoker RDF spreader stoker and a Babcock and Wilcox controlled combustion zone boiler. The combustion zone boiler is rated at 158,200 MJ/h ($150 \times 10^6$ Btu/h) of steam.

The stoker is a traveling grate located at the bottom of the boiler. The fuel from the feeders enters the front of the boiler. A single auxiliary burner capable of using natural gas and No. 2 fuel oil is located on the right sidewall above the primary combustion zone. It can be used for startup, shutdown, or to maintain stable combustion conditions. The sulfur content of the natural gas and fuel oil is limited by the air permit to a maximum of 0.7%.

The boiler is balanced draft. One fan (forced-draft) is used to feed combustion air, and the second fan (induced-draft) located ahead of the stack is used to draw out the combustion gases. A control system based on $O_2$ and CO concentrations is used to optimize combustion efficiency. The target level of excess oxygen is in the range of 7% to 8% on a dry basis.

In addition to the waterwalls in the combustion zone, the heat recovery system includes superheater, economizer, and combustion air heater sections. At the exit to the air heater, the flue gas temperature is approximately 204°C (400°F).

### 3.1.4 Cyclone, Spray Dryer, and Fabric Filter

The combustion gases from the air heater enter a multicyclone dust collector which removes large particulate. Next, an alkaline spray dryer is used to control acid gas emissions. The spray dryer is a reaction vessel where lime slurry is sprayed into the flue gas that contains PM, acid gases, and other pollutants in gaseous and aerosol form. The slurry water is evaporated

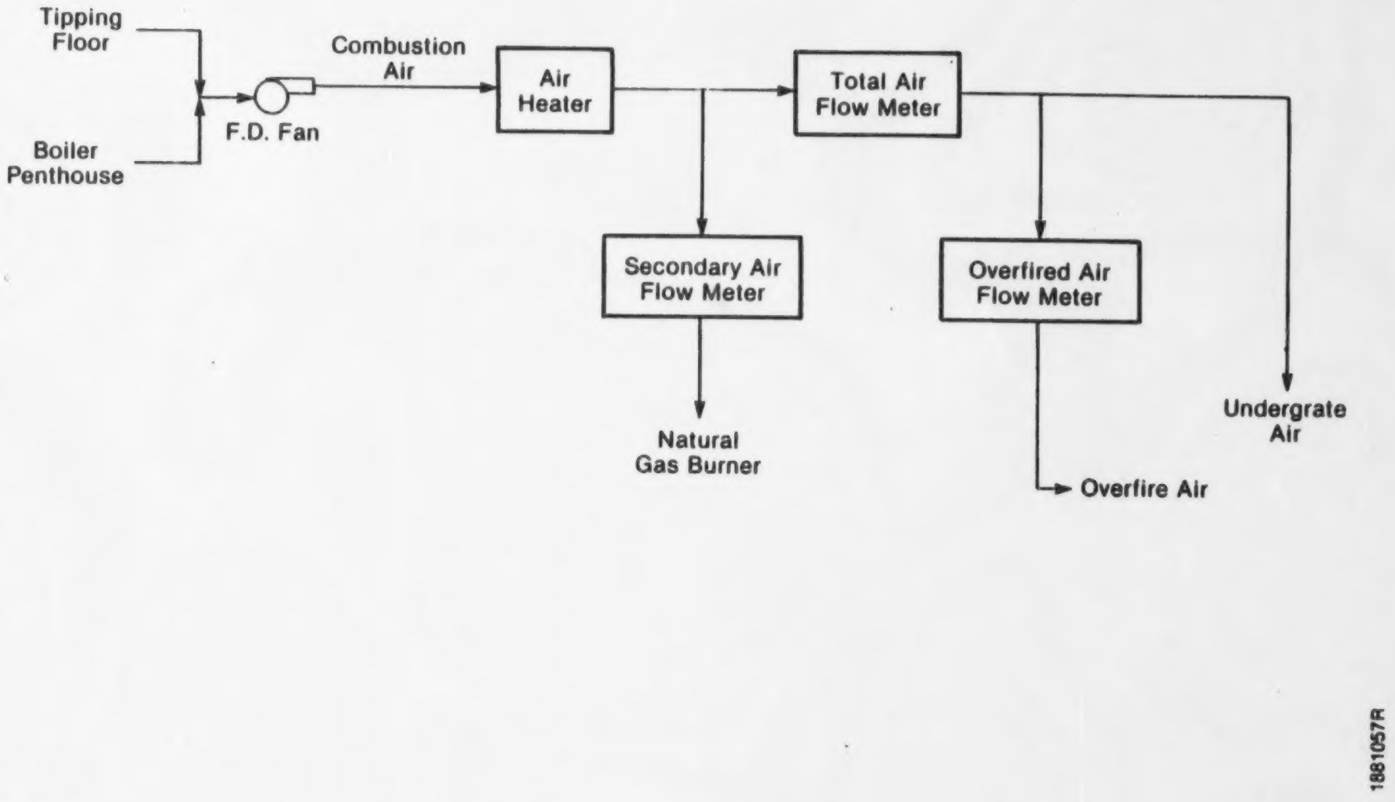

Tipping Floor
Boiler Penthouse
F.D. Fan
Combustion Air
Air Heater
Secondary Air Flow Meter
Natural Gas Burner
Total Air Flow Meter
Overfired Air Flow Meter
Overfire Air
Undergrate Air
1881057R

Figure 3-3. Combustion Air Scheme at the MERC Facility.

by the flue gas heat and the acid gases react with the lime. Particulate and excess lime serve as nucleation points for adsorption and agglomeration of volatile trace metals and semivolatile organics.

The rate of lime addition and the flue gas temperature at the exit to the spray dryer can be controlled separately. Slaked lime, which is introduced as a slurry, is diluted with water before it enters the reaction vessel at rates appropriate to achieve the desired $SO_2$ concentration at the inlet to the fabric filter. The rate of slurry addition is varied based on the continuously monitored $SO_2$ concentration at the outlet of the fabric filter.

The facility is required by its operating permit to maintain an outlet $SO_2$ concentration of < 30 ppm. At no time during the test program, however, were the facility's $SO_2$ monitors providing accurate readings. The spray dryer outlet temperature is directly controlled by the amount of diluting water added and is typically 138° to 149°C (280° to 300°F).

The fabric filter collects the particulate from the gas stream. The excess lime in the bag filter cake provides a second-stage reaction site for further acid gas removal. The fabric filter unit has six modules. In a continuous cycle, five modules filter flue gas while one module is being cleaned. The total time to complete a fabric filter cleaning cycle is about 18 minutes.

### 3.1.5 Ash Handling

The ash system removes ash from the stoker discharge quench pit, generating bank hopper, air heater hopper, mechanical dust collector hopper, spray dryer hopper, and fabric filter module hoppers. All of the hopper discharges are through rotary seal valves. This ensures a positive seal to prevent boiler gases from entering the ash conveyors and air from entering the hoppers and boilers.

The ash from the fabric filter modules discharges into six identical drag/screw conveyors. Each set of these conveyors discharges into one of two identical drag chain collecting conveyors. The spray dryer and mechanical dust collector discharge ash directly onto these drag chain collecting conveyors. The generating hopper and air heater hopper discharge ash onto a transverse drag conveyor which feeds to the drag chain collecting conveyors. The combined fly ash from each collecting conveyor is fed to one of two identical ash conditioning screw conveyors. The ash is conditioned by water added at a controlled rate.

The bottom ash from each stoker discharges into one of two submerged drag chain ash conveyors. The discharge of the ash conditioners is deposited into the dewatering section of the bottom ash drag conveyor. At this point, the fly and bottom ash streams combine. The combined ash streams are then dumped into a specially designed trailer for removal from the site.

Dust control within the processing building is achieved through two separate control systems. One system serves the tipping/processing area, while the other serves the conveyors in the boiler building and RDF reclaim area.

Each system contains a baghouse, fan duct hoods, and dust collection ducts at key conveyor and transfer processing points. Dust-laden air is drawn through one of two pulsed jet baghouses which exhaust in the vicinity of the boiler forced-draft fan intake. The baghouse air exhaust is thus incorporated into the combustion air for the boilers. Dust captured by the baghouses is returned to and becomes a part of the RDF fuel.

## 3.2 SUMMARY OF OPERATIONS BY TEST RUN

Three test runs were conducted on Unit A from December 9-12, 1987. During each test run RDF only was fired.

### 3.2.1 Operations During Run 1

Run 1 was originally scheduled for December 8, but power problems in the afternoon delayed it until December 9. Both units were down overnight and the facility was still experiencing operational problems on the morning of December 9. The units were started up in the morning and were preheated on natural gas. However, problems with the feeder conveyors delayed bringing the boilers up to full load until 1400. At 1500, CEM data indicated that the boilers were stabilized.

Test 1 began at 1530 and continued until approximately 1840 when the Unit A forced-draft fan failed. Two of three traverses (160 min) had been completed at the time of the shutdown. Since replacement of the fan motor required overnight work, Test 1 was considered to be completed by EPA personnel on site.

### 3.2.2 Operations During Run 2

Run 2 was conducted on December 10, 1987. The fan was repaired at approximately 0100 that morning and both units were back on-line. However, at 1030 there was a feeder conveyor failure and a unit shutdown occurred. The units were brought back on-line at 1200, and Test 2 began at 1245. Testing continued and was completed at 1800. All three traverse ports were sampled for a complete run (240 min).

The facility operators decided to increase the lime slurry feed rate at 1330. Minor excursions of $SO_2$ were being experienced and the facility did not want to exceed its permit limit of 30 ppm. Therefore, the lime slurry feed rate was increased from approximately 3 gpm to values ranging from 7 to 8 gpm. The test average was 7.8 gpm. This increase substantially reduced the $SO_2$ concentration at the midpoint and outlet locations.

### 3.2.3 Operations During Run 3

Run 3 was conducted on December 12, 1987. Originally scheduled for December 11, problems had continued with feeder conveyors throughout the day on the 11th, so testing was postponed until the 12th. Test 3 began at 1115. A brief test interruption occurred between 1138 and 1200 due to a feeder malfunction. Testing continued until 1525, restarted at 1815, but was stopped at 1830 due to recurring feeder problems. Throughout run 3, the lime slurry rate was maintained between 7 and 8 gpm. Due to the late hour and the fact that the facility estimated that the delay time would be 4 to 8 h, the test was considered complete at the end of two complete port traverses plus three of eight points for the third (190 min).

## 3.3 SUMMARY OF KEY OPERATING PARAMETERS

This section summarizes the values of key operating parameters during the test program. The purpose of evaluating the operating parameters was to determine: (a) if the system was operating at normal conditions, and (b) if the system was operating at similar conditions during each of the three test runs. Only selected key parameters are discussed in this section.

The operating data were recorded by computer every 4 min. The complete set of operating data showing each 4-min value is included in Appendix B. Plots of the 4-min data versus time are presented in this section. The plots have been reduced so that all three runs can be shown on one page. Full-sized plots for each run are included in Appendix B if more detail is required by the reader. The locations of temperature, pressure, and flow sensors are indicated in Figure 3-4.

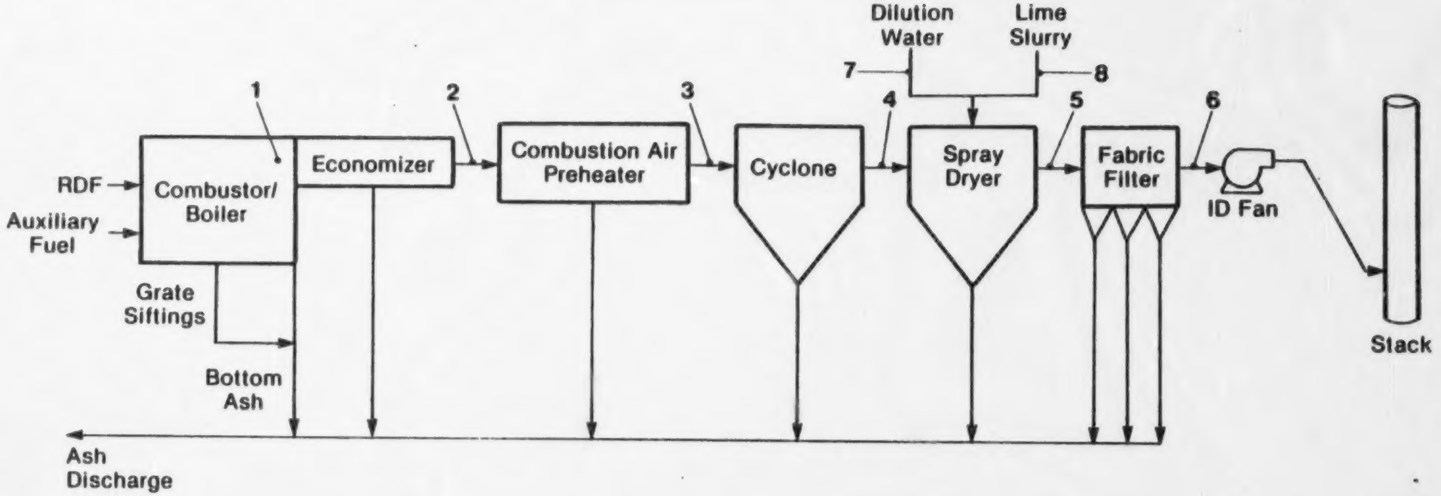
Average values for selected operating parameters over the actual testing intervals are summarized in Table 2-1. On average, the combustor operating conditions appear to be the same for all three runs. The only variation of consequence is the higher airflow and economizer inlet flue gas temperature during run 3. Although the combustion operating conditions appear similar, there is no way to judge if the entire combustor system reached the same degree of thermal equilibrium for each run.

The emission control system was operated differently during each run. The average lime slurry feed rate was increased during each test, with run 2 being higher than run 1, and run 3 being higher than run 2. This increase in slurry flow, combined with the higher spray dryer inlet temperature and airflow during run 3, is consistent with the increase in pressure drop across the spray dryer and fabric filter during each test.

### 3.3.1 Steam Load and Heat Release

In Figure 3-5, RDF heat release, superheater steam flow, superheater steam pressure, and steam temperature at the superheater outlet are plotted against time. The RDF heat release is calculated from the steam flow minus the heat content supplied by any auxiliary fuel (natural gas or fuel oil). During this test program, only RDF was fired, and sampling was discontinued during periods when auxiliary natural gas firing was necessary. Thus, for this test program, the RDF heat release is equivalent to the total heat release.

For all three runs, these combustion parameters were similar and normal during the time periods in which the manual sampling trains were operating. The relative standard deviation of the steam load averaged 4% during the sampling periods.


Dilution Water
Lime Slurry
7
8
1
2
3
4
5
6
RDF
Auxiliary Fuel
Combustor/ Boiler
Economizer
Combustion Air Preheater
Cyclone
Spray Dryer
Fabric Filter
ID Fan
Stack
Grate Siftings
Bottom Ash
Ash Discharge

1 - Superheater steam flowrate, pressure, temperature and economizer inlet flue gas temperature
2 - Economizer outlet flue gas temperature and excess oxygen
3 - Air heater outlet flue gas temperature and pressure
4 - Spray dryer inlet flue gas temperature and pressure
5 - Spray dryer outlet flue gas temperature and pressure
6 - Fabric filter outlet temperature
7 - Dilution water feedrate
8 - Lime slurry feedrate

Figure 3-4. Location of Important Temperature, Pressure, and Flow Sensors at the MERC Facility.

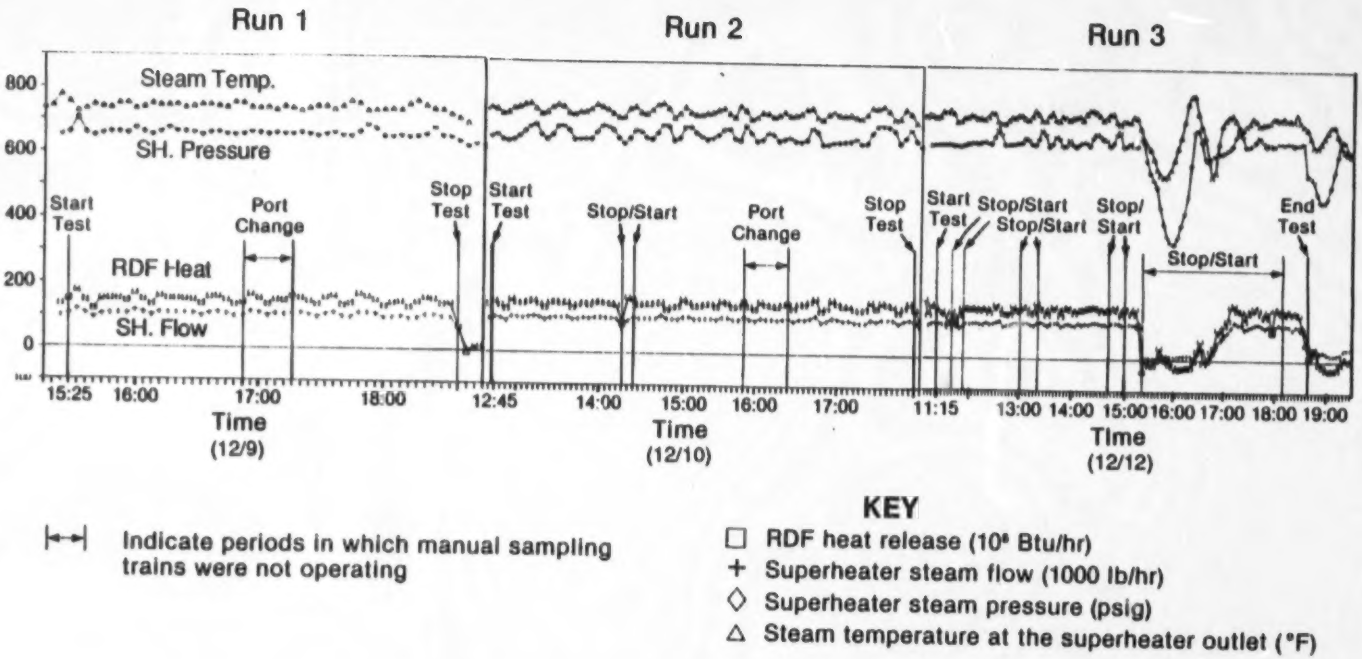


Figure 3-5. RDF Heat Release Steam Flow, Steam Temperature, and Steam Pressure as a Function of Time During the MERC Test Program.

### 3.3.2 Combustion Air

Overfire air distribution, undergrate-to-furnace differential pressure, and excess oxygen are plotted against time in Figure 3-6. The overfire air distribution was calculated by dividing the overfire air mass flow rate by the total mass flow rate.

The variation in excess oxygen was greater during run 3 than in runs 1 and 2. During run 3, the relative standard deviation was 22%, as compared to 16% and 12% for runs 1 and 2. However, the average concentrations were not significantly different.

The overfire air (OF) distribution was lower and undergrate-furnace differential pressure was higher during run 3. The average OF air distribution was 60% during runs 1 and 2, but decreased to 50% during run 3. The undergrate-furnace differential pressure increased to 0.4 in $H_2O$ during run 3 from 0.3 in $H_2O$ during run 2. It was 0.5 in run 1.

The overfire airflow pressures were measured in the combustor. The pressures measured during the MERC test program are presented in Figure 3-7. As the figure shows, once the combustor is optimized, the pressures do not vary. Pressurized air from two airswept spouts is also used to spray the RDF across the grate as it enters the combustor. The airswept pressure is varied in a set range so that the RDF is sprayed evenly across the grate.

### 3.3.3 Temperature Profile

The inlet and outlet flue gas temperatures of the economizer, air heater, spray dryer, and fabric filter are plotted against time in Figure 3-8. The economizer inlet, economizer outlet, and air heater outlet temperatures were 10 to 20 degrees hotter during run 3. However, after the spray dryer, the flue gas temperature during run 3 was the same as during runs 1 and 2. The spray dryer outlet temperature was very consistent during all three runs.

### 3.3.4 Spray Dryer and Fabric Filter

The operation of the spray dryer and fabric filter was evaluated using two plots. The first plot (Figure 3-9) included the spray dryer inlet and outlet temperatures, the lime slurry and dilution water feed rates, and the fabric filter differential pressure. The second plot (Figure 3-10) includes the flue gas differential pressures across the cyclone, spray dryer and fabric filter.

The differences in spray dryer operation during the runs are shown clearly in Figure 3-9. During run 2, the lime slurry feed rate was increased significantly because of the high $SO_2$ concentration monitored at the fabric filter outlet by the test conductor (more than double the permit level of 30 ppm). The lime slurry feed rate was increased from 3 gpm to over 7 gpm and remained at this level through run 3. A corresponding decrease in the dilution water feed rate was observed such that the total feed rate of lime slurry and dilution water increased only slightly. The spray dryer outlet temperature remained constant throughout all three test runs.

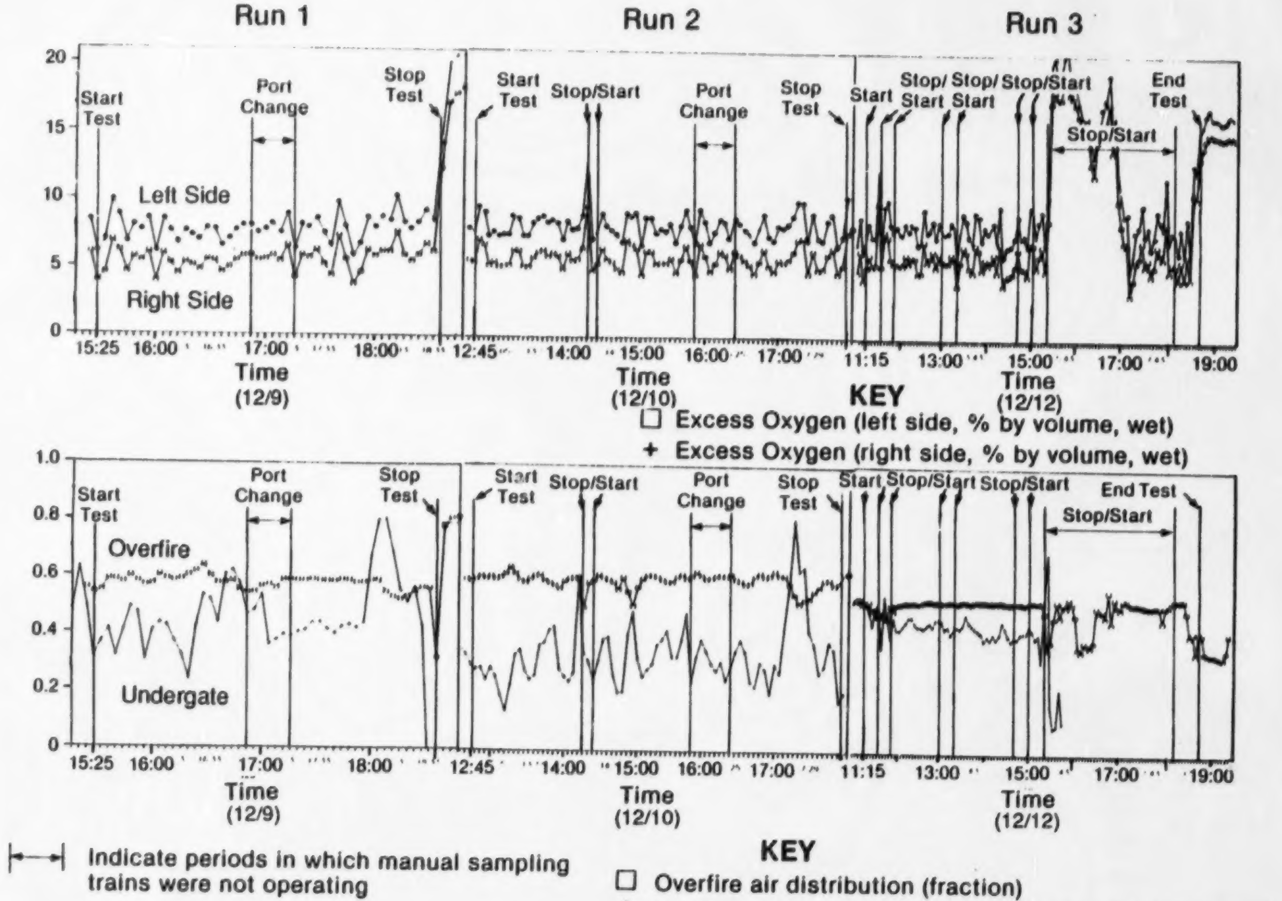
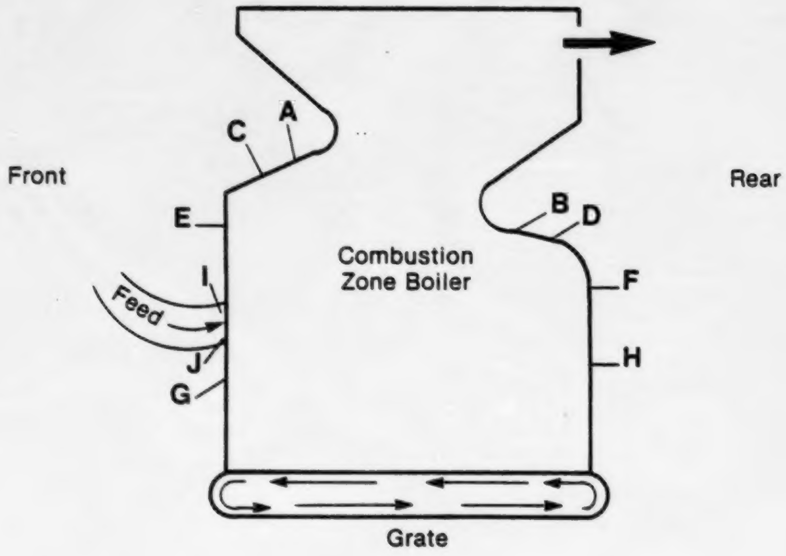


Figure 3-6. Combustion Air Pressure as a Function of Time During the MERC Test Program.


Front
Rear
A
C
B
D
E
F
H
I
J
G
Feed
Combustion Zone Boiler
Grate

Pressure (in $H_2O$)

A - 23"
B - 24"
C - 23"
D - 24"
E - 23"
F - 24"
G - 13"
H - 24"
I - Airswept Spout - Range of 9" to 24"
J - Airswept Spout - Range of 9" to 24"

Figure 3-7. Overfire Air Flow Pressure Measured During the MERC Test Program.

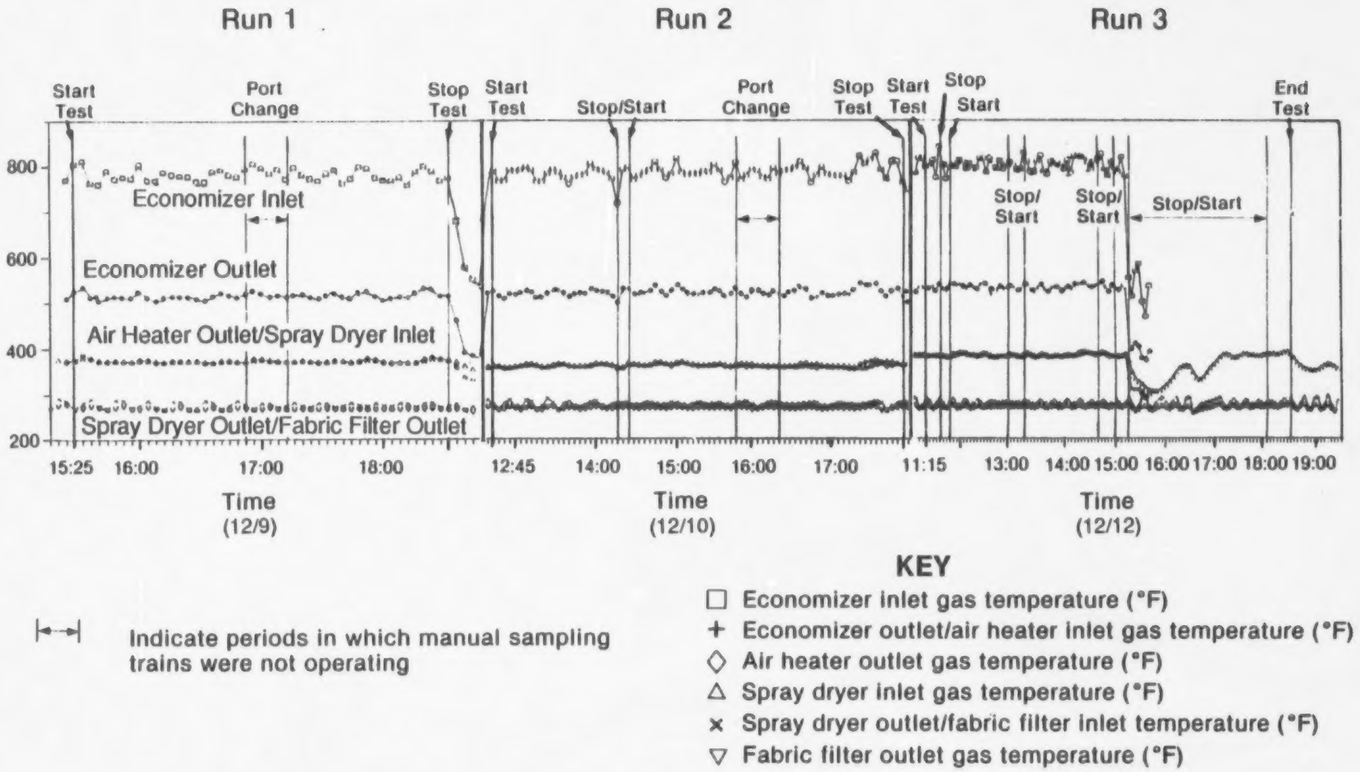


Figure 3-8. Flue Gas Temperature as a Function of Time During the MERC Test Program.

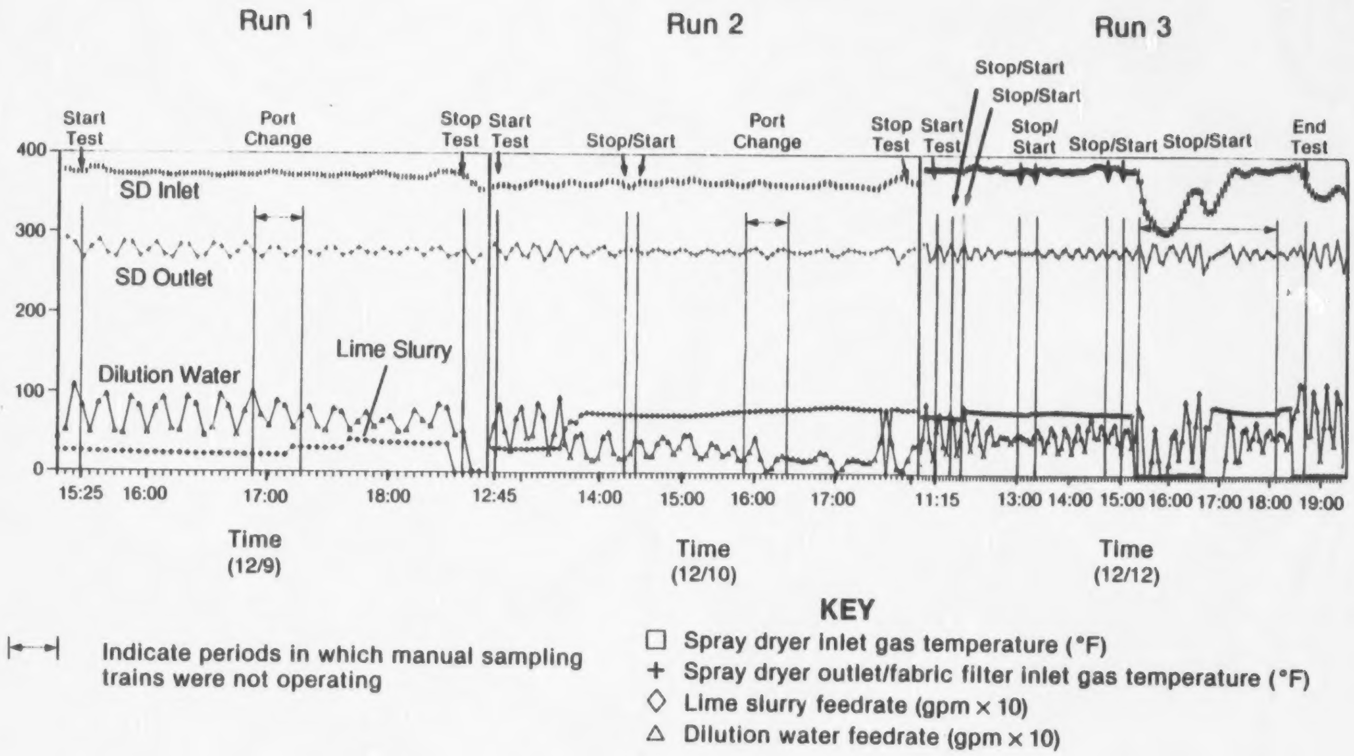


Figure 3-9. Spray Dryer Operating Parameters as a Function of Time During the MERC Test Program.

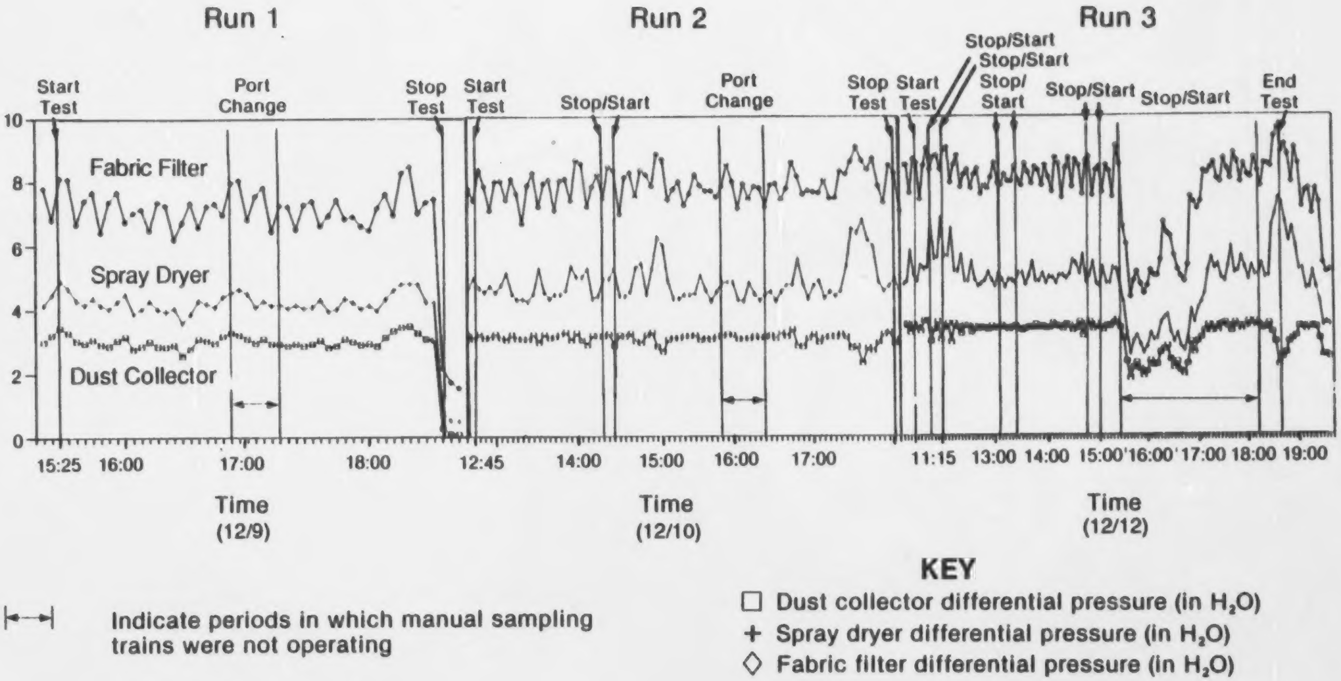


Figure 3-10. Differential Pressures Across the Control Devices During the MERC Test Program.

The differential pressures across all three control devices (cyclone, spray dryer, and fabric filter) increased during runs 2 and 3, with run 3 being the highest. For run 2, the increase in lime slurry may have caused the increase, since the pressure drop across the cyclone did not change significantly. However, for run 3, a combination of increased airflow rate and lime slurry may have caused the increased pressure drop.

# SECTION 4.0

# SAMPLING LOCATIONS

Sampling locations for unit A are shown in the process line schematic in Figure 4-1. Each sampling location is discussed in the following sections.

## 4.1 SPRAY DRYER INLET

Parameters that were measured at the spray dryer inlet (location 1 in Figure 4-1) included PCDD/PCDF, HCl, $SO_2$, PM, Pb, Hg, Cd, Cr, As, THC, $CO_2$, CO, and $O_2$. A side view and top view of the sampling location are shown in Figure 4-2. The sampling location had four 10-cm (4-in.) inside diameter flanged ports on the side of a horizontal rectangular duct with a cross-sectional area of 1.544 $m^2$ (16.62 $ft^2$). Three of these ports gave access to the cross-sectional plane used for the full traverse MM5 and Method 3 sampling. The fourth port, located 1.22 m (4 ft) downstream, was used for the CEMS probes at a fixed sampling point near the center of the duct. All of the ports had 23-cm (9-in.) nipples and were accessible from the floor at the top of the spray dryer.

EPA Method 1 was used to select the number and location of the sampling points for MM5 and Method 3 sampling. Those ports were located approximately one equivalent duct diameter 1.22 m (4 ft, 1 in.) downstream of an expansion joint and 1.4 duct diameters upstream of the spray dryer inlet. Twenty-four traverse points were required, and the point location diagram is presented in Figure 4-2.

A cyclonic flow check was conducted prior to sampling. The average degree of rotation was two degrees. This met the criterion in Method 1 which specifies that the average degree of rotation must be no greater than 20 degrees.

The average volumetric gas flow rate and temperature in the duct during the three test runs was 1,170 dscm/min (41,000 dscfm) and 191°C (376°F). The average static pressure was -215 mm $H_2O$ (-8.5 in. $H_2O$).

## 4.2 SPRAY DRYER OUTLET/BAGHOUSE INLET

Parameters that were measured at the spray dryer outlet (location 2 in Figure 4-1) were HCl, carbon dioxide, and oxygen. The sampling location had three 10-cm (4-in.) ports on top of a horizontal rectangular duct with a cross-sectional area of 1.839 $m^2$ (19.79 $ft^2$). Two of these ports were used for the CEMS probes at fixed sampling points near the center of the duct. The ports were accessible from the top of the duct. These ports were located

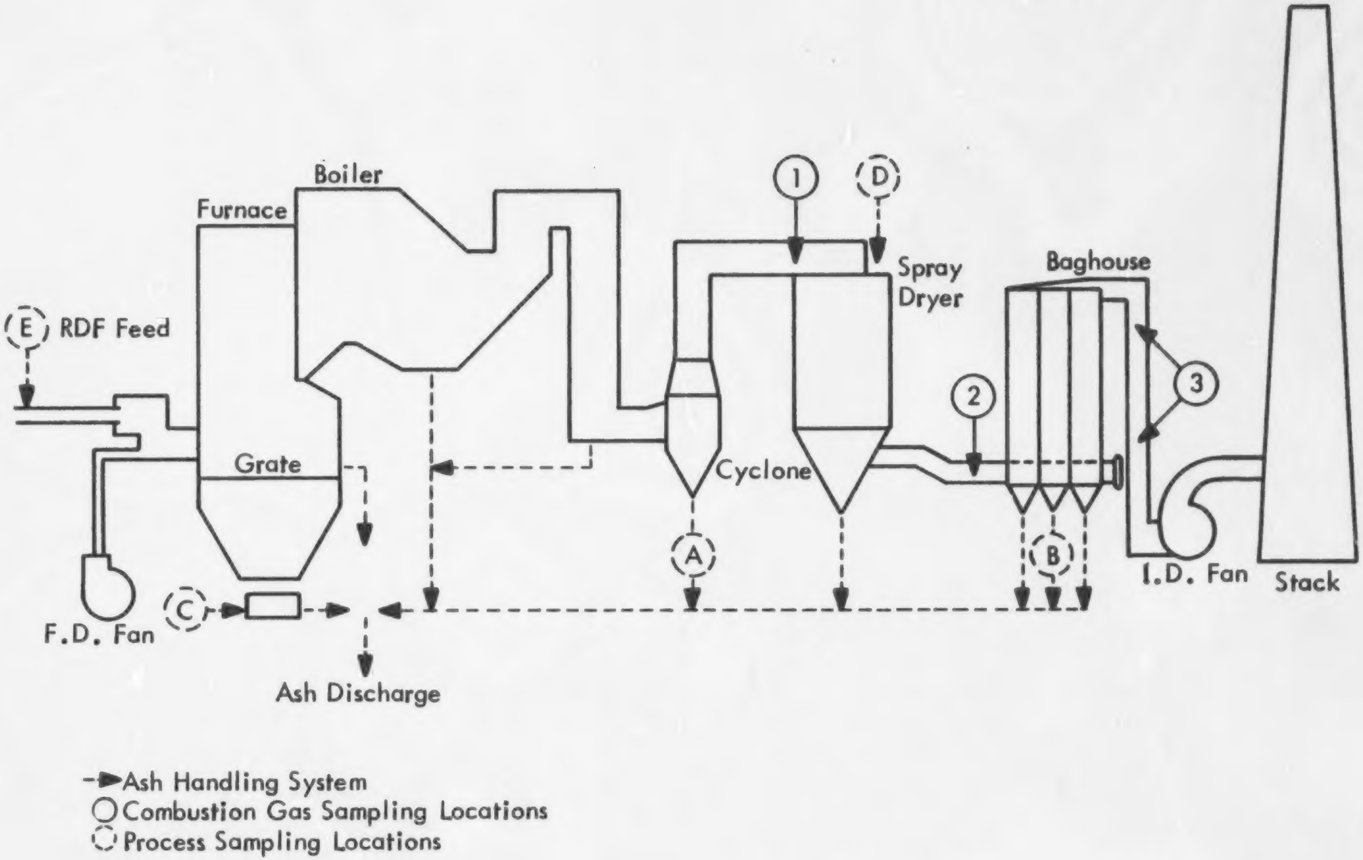
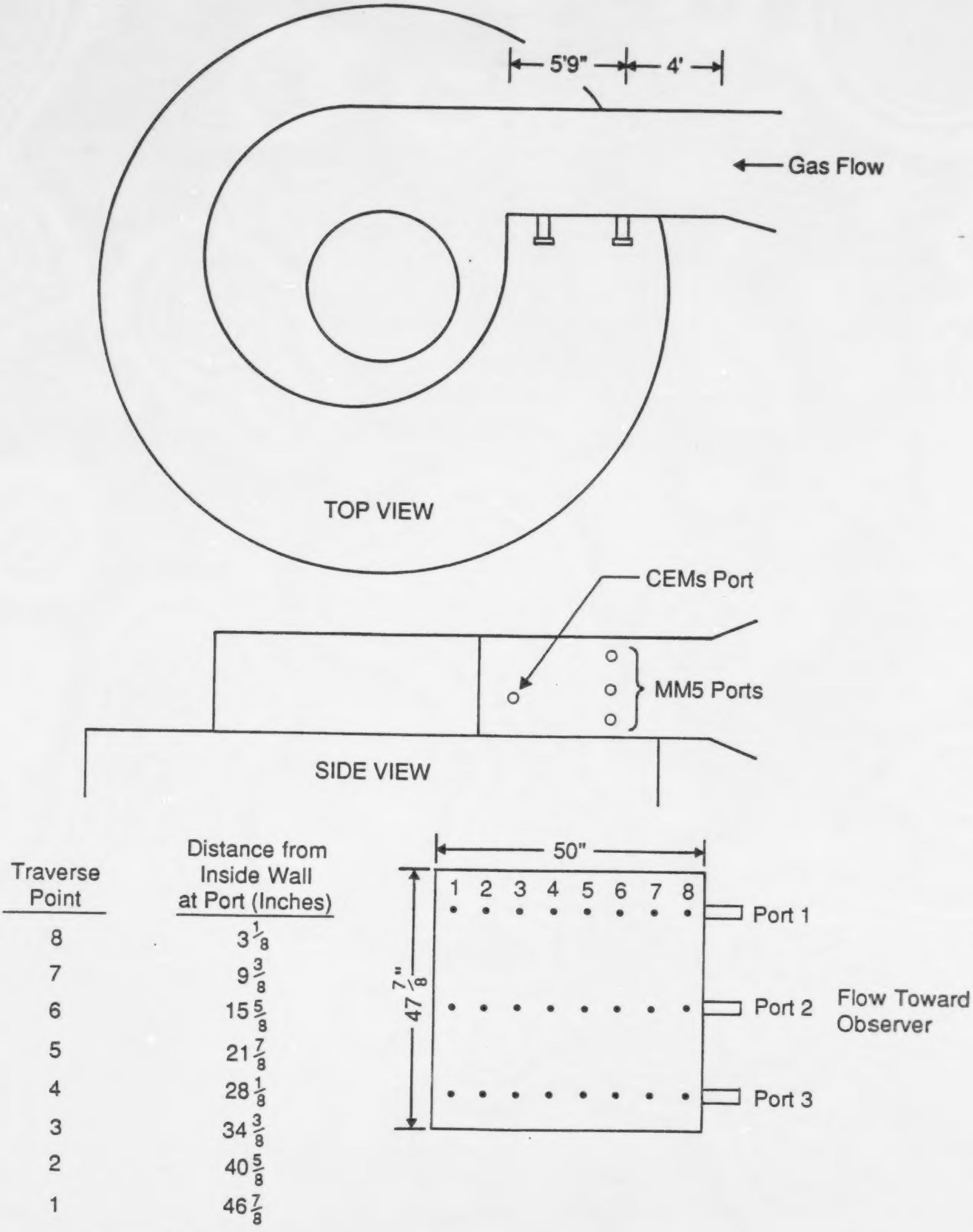

(E) RDF Feed
Furnace
Boiler
Grate
F.D. Fan
(C)
Ash Discharge
(1)
(D)
Spray Dryer
Cyclone
(A)
(2)
Baghouse
(B)
(3)
I.D. Fan
Stack
Ash Handling System
Combustion Gas Sampling Locations
Process Sampling Locations

Figure 4-1. Sampling and Monitoring Locations--Unit A.


5'9"
4'
Gas Flow
TOP VIEW
CEMs Port
MM5 Ports
SIDE VIEW
50"
1 2 3 4 5 6 7 8
$47\frac{7}{8}$"
Port 1
Port 2
Port 3
Flow Toward Observer

| Traverse Point | Distance from Inside Wall at Port (Inches) |
|---|---|
| 8 | $3\frac{1}{8}$ |
| 7 | $9\frac{3}{8}$ |
| 6 | $15\frac{5}{8}$ |
| 5 | $21\frac{7}{8}$ |
| 4 | $28\frac{1}{8}$ |
| 3 | $34\frac{3}{8}$ |
| 2 | $40\frac{5}{8}$ |
| 1 | $46\frac{7}{8}$ |

Figure 4-2. Spray Dryer Inlet--Location of Sampling Ports and Traverse Points.

approximately 1.4 duct diameters (1 duct diameter = 1.35 m = 4 ft, 5 in.) downstream from a bend in the duct and 1.1 duct diameters upstream from the first pair of baghouse module inlets.

## 4.3 BAGHOUSE OUTLET

Parameters that were measured at the baghouse outlet (location 3 in Figure 4-1) included PCDD/PCDF, HCl, $SO_2$, $NO_x$, carbon dioxide, oxygen, particulate, lead, mercury, cadmium, chromium, and arsenic. Two side views of the sampling location are shown in Figure 4-3. There were two sampling locations on the duct. Each had three 10-cm (4-in.) inside diameter flanged ports located on one side of the vertical rectangular duct. The three ports at each location gave access to a cross-sectional plane of 1.839 $m^2$ (19.79 $ft^2$) in the duct having an equivalent diameter of 1.35 m (4 ft, 5 in.).

Two of the ports at the upstream location were used for the CEMS probes at fixed sampling points near the center of the duct. These ports were accessible from a permanent platform located approximately 1.52 m (5 ft) below the ports. The ports were located 1.8 duct diameters downstream of a 90-degree duct bend and 3.6 duct diameters upstream of the dampered bypass duct.

The ports at the downstream location were used for the MM5 and M3 sampling and were accessible from the top of the bypass duct. These ports were located approximately 4.3 duct diameters downstream of a 90-degree duct bend and 1.1 duct diameters upstream of the dampered bypass duct. Twenty-four traverse points were required according to Method 1, and the point location diagram is presented in Figure 4-3. A cyclonic flow check yielded an average rotation of four degrees.

The average volumetric gas flow rate and temperature measured at the downstream location during the three test runs was 1,170 dscm/min (41,200 dscfm) and 133°C (271°F). The average static pressure was -512 mm $H_2O$ (-20.2 in. $H_2O$).

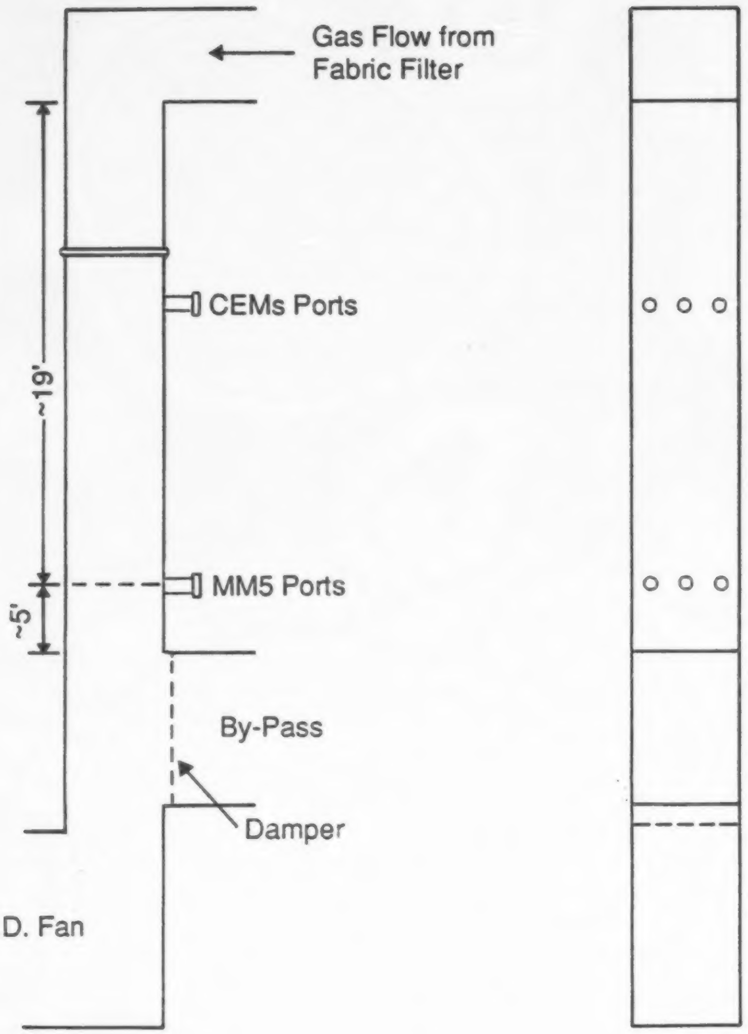
## 4.4 CYCLONE COLLECTOR ASH

Cyclone collector ash was sampled from a 5-cm (2-in.) gate-valved discharge pipe (location A in Figure 4-1) connected to the bottom of the larger inclined pipe that transferred the ash from the rotary seal valve on the bottom of the hopper to the drag chain conveyor.

The original scope for mass ash collection sampling at this location was not accomplished. Ash could not be mass sampled due to the expense and manpower that would have been required to reroute the inclined pipe before and after each test run.

## 4.5 BAGHOUSE ASH

Baghouse ash was sampled from a 5-cm (2-in.) gate-valved discharge pipe connected to the bottom of the horizontal drag/screw conveyor approximately 3.05 m (10 ft) downstream from the rotary seal valve discharge on the bottom of the hopper on unit A baghouse compartment 5.


Gas Flow from Fabric Filter
CEMs Ports
~19'
MM5 Ports
~5'
By-Pass
Damper
To I.D. Fan

| Traverse Point | Distance from Inside Wall at Port (Inches) |
|---|---|
| 8 | $3\frac{1}{8}$ |
| 7 | $9\frac{3}{8}$ |
| 6 | $15\frac{5}{8}$ |
| 5 | $21\frac{7}{8}$ |
| 4 | $28\frac{1}{8}$ |
| 3 | $34\frac{3}{8}$ |
| 2 | $40\frac{5}{8}$ |
| 1 | $46\frac{7}{8}$ |

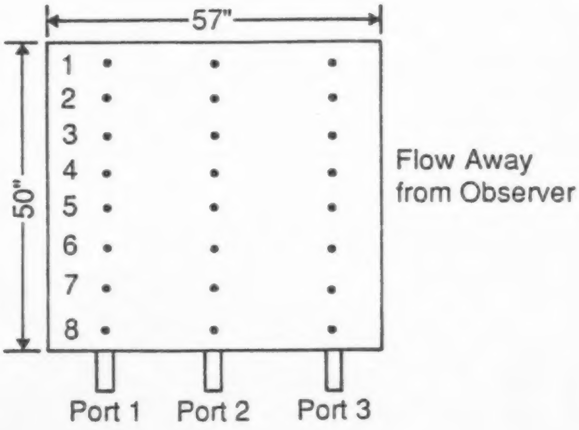

57"
50"
1
2
3
4
5
6
7
8
Flow Away from Observer
Port 1
Port 2
Port 3

Figure 4-3. Baghouse Outlet--Location of Sampling Points and Traverse Points.

This was the only location where uncontaminated baghouse ash could be sampled, because the expense of installing pipes on the other five conveyors and the extra time required to collect those samples were not warranted. The samples taken from one compartment were representative of the total baghouse discharge because of the gas flow distribution and the overlapping of compartment cleaning cycles.

## 4.6 BOTTOM ASH

Furnace bottom ash was sampled from the drag chain conveyor leaving the quench pit beneath the furnace bottom and ash chute (location C in Figure 4-1). Samples could not be collected before the quench without making costly modifications to the bottom ash chute so as to keep ambient air from entering the furnace at the sampling point. Also, samples taken from such a point probably would not have been representative of the bottom ash.

The bottom ash samples taken after the quench pit could have been contaminated occasionally by overflow from the conveyor systems that were moving ash from the baghouses and all collection points in units A and B. When screw conveyors moving ash from the drag chain conveyors to the final ash discharge were overloaded or obstructed, the ash from these conveyors overflowed into the quench pit. Also, the Unit A bottom ash discharge was downstream of the Unit B discharge. Therefore, when Unit B was operating, the bottom ash samples represented ash from both units. However, both units are identical and the RDF feed to both are from a common source.

## 4.7 LIME SLURRY

Lime slurry samples were taken from the main feed line at a tap (location D in Figure 4-1) located within 6.10 m (20 ft) of the injection point at the top of the spray dryer. This sampling location was ideal for obtaining representative sample increments immediately upstream of the slurry injection.

## 4.8 REFUSE DERIVED FUEL

During run 1, RDF samples were taken from a point along the process conveyor belt, A-16 (location E in Figure 4-1). During runs 2 and 3, RDF samples were taken from the A-17 feed line immediately before injection into the furnace.

## 4.9 SAMPLES NOT COLLECTED

Samples were not collected directly from the spray dryer ash discharge hopper, because it had been assumed that very little ash, if any, accumulated in the hopper. A gate-valved pipe attached to the hopper was opened and no ash flow resulted. However, this could have been due to the negative pressure at that point. Physical constraints made it impossible to collect samples after the rotary seal valve.

Preheater, economizer, and grate siftings ashes were not part of the test protocol and were not sampled.

# SECTION 5.0

# SAMPLING AND ANALYSIS PROCEDURES

The descriptions of the sampling and analysis methods provided in this section are brief. Detailed descriptions are included in Appendix M. The sampling and analysis methods used for each parameter are summarized in Table 5-1.

## 5.1 DIOXIN/FURAN SAMPLING AND ANALYSIS

### 5.1.1 Sampling Equipment Preparation

Combustion gas samples for dioxin/furan (PCDD/PCDF) analysis were collected using a Modified Method 5 (MM5) sampling train. Figure 5-1 shows details of this train. Space restrictions at the spray dryer inlet location additionally required the probe connection at the sample box to be connected with a flexible heated 1.22-m (4-ft) Teflon line and a glass union. Remaining assembly of the sampling train followed the procedure outlined in S-1, Standard Operating Procedure for MM5 train, located in Appendix M-1. Figure 5-2 shows a data sheet for the field lab setup.

5.1.1.1 XAD-2 Cleanup and Trap Preparation--

Adsorbent resin used for the testing was XAD-2 (Alltech Associates/Applied Science, 20/50 mesh, 90 Å pore size), Soxhlet extracted with methylene chloride. The resin is then dried overnight with a gentle stream of prepurified nitrogen.

5.1.1.2 Storage of Extracted XAD-2--

Any precleaned XAD-2 resin not used immediately (within 2 weeks) was stored under high purity methanol until needed. Traps were packed with dry XAD and sealed with glass plugs. XAD cartridges must then be used within 2 weeks of packing.

5.1.1.3 Glassware Cleaning--

Prior to testing, all sampling train glassware was cleaned and individual pieces were marked. A data sheet for each assembled train was filled out, detailing precisely which pieces of glassware were used. All glassware used for collection or storage of organic semivolatile compounds was cleaned according to the following procedure:

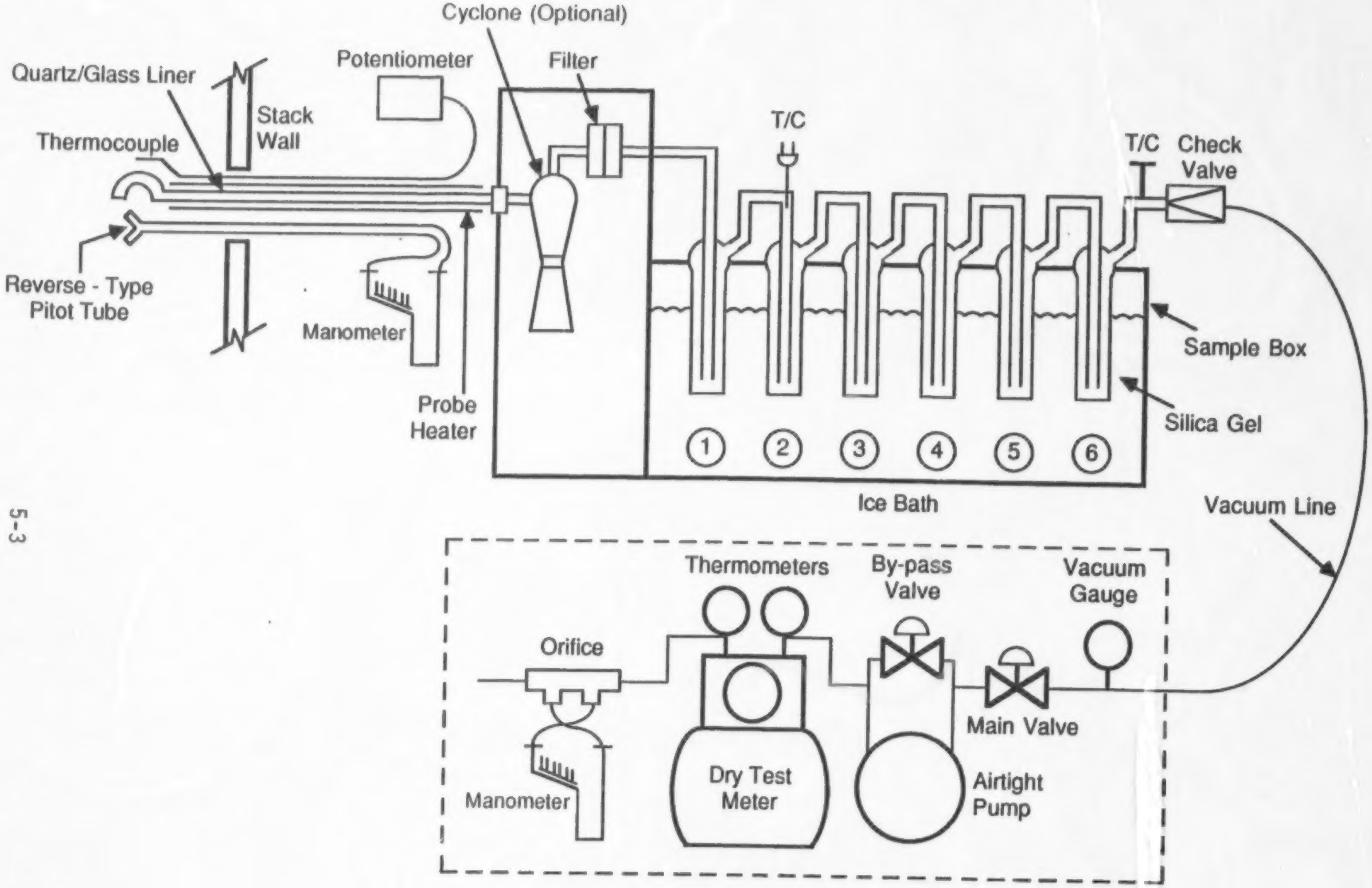
1. Wash in hot soapy water (Alconox or equivalent).
2. Rinse five times with tap water.

TABLE 5-1. SUMMARY OF SAMPLING AND ANALYTICAL PROCEDURES

| Parameters | Sampling method | Analytical method |
|---|---|---|
| Particulate | MM5 combined train with metals | Gravimetric |
| Metals (Cd, Cr, As, Pb, Hg) | MM5 combined train with particulate | ICAP/AAS |
| Molecular weight | M3 | Orsat |
| PCDD/PCDF | MM5 | HRGC/MS |
| Cyclone ash | Composite grab sample | ICAP/AAS (metals)<br>*ASTM E777 (% combustibles)<br>ASTM D3174 (% carbon) |
| Fabric filter ash | Composite grab sample | ICAP/AAS (metals)<br>*ASTM E777 (% combustible)<br>ASTM D3174 (% carbon)<br>IEEE 548-1984 (resistivity) |
| Bottom ash | Composite grab sample | ICAP/AAS (metals)<br>*ASTM E777 (% combustible)<br>ASTM D3174 (% carbon) |
| Lime slurry | Single grab sample | ICAP/AAS (metals)<br>% Lime<br>Specific gravity |
| CEMS | $CO_2$ | NDIR analyzer |
|  | $O_2$ | Paramagnetic and polarographic analyzer |
|  | CO | NDIR analyzer |
|  | $NO_x$ | Chemiluminescence |
|  | $SO_2$ | Electrochemical |
|  | HCl | Various (refer to Entropy report) |

---

* Actually Galbraith Laboratories Method ME-6 based upon the ASTM method, but utilizes a Leco CR-12 IR detector for analysis.


Cyclone (Optional)
Potentiometer
Filter
Quartz/Glass Liner
Stack Wall
Thermocouple
T/C
T/C
Check Valve
Reverse - Type Pitot Tube
Manometer
Probe Heater
Sample Box
Silica Gel
①
②
③
④
⑤
⑥
Ice Bath
Vacuum Line
Thermometers
By-pass Valve
Vacuum Gauge
Orifice
Main Valve
Dry Test Meter
Airtight Pump
Manometer

① Condenser with Ice Water Jacket
② XAD Resin Cartridge with Ice Water Jacket
③ Modified Greenburg-Smith Impinger,100mL of Double Distilled in Glass $H_2O$
④ Modified Greenburg-Smith Impinger, 100mL of Double Distilled in Glass $H_2O$
⑤ Modified Greenburg-Smith Impinger, Empty
⑥ Modified Greenburg-Smith Impinger, $SiO_2$

Figure 5-1. Modified Method 5 Sampling Train for Semivolatile Organic Compounds.

# MODIFIED METHOD 5 TRAIN
# SEMIVOLATILE ORGANICS SAMPLING
# FIELD LAB SET UP DATA

Project No. 8910 L (02-12)

Plant: Maine Energy Recovery Co., Biddeford, ME

Run No. ______

Sampling Location: Unit A,

Sampling Train No. ______

Sample Box No. ______

Sample Box Set Up Date/Person: ______

Sample Box Leak Check: ______ cfm @ ______ in. Hg vacuum

Train to be used for:
Source Sample
Pre-Run Proof Blank
Post-Run Proof Blank
Location Blank

| TRAIN COMPONENT | COMPONENT NO. | LOADING DATA | Initial Weight (grams) |
|---|---|---|---|
| Nozzle | | | |
| Probe | | | |
| ♀ Probe Blank-off | | | |
| ♂ Glass Union Blank-off | | | |
| Glass Union | | | |
| Sample Transfer Line | | | |
| ♀ S-T Line Blank-off | | | |
| Cyclone | | | |
| Flask | | | |
| Long 90° Adapter | | | |
| Filter Holder Front | | Filter No.: | |
| Filter Holder Back | | | |
| Short 90° Adapter | | | |
| Condenser | | | |
| T/C-well U-Adapter | | | |
| XAD Cartridge | | | |
| U-Adapter (A) | | | |
| 3rd Impinger Mod-GBS | | 100 mls D.I. $H_2O$ | |
| U-Adapter (B) | | | |
| 4th Impinger GBS | | 100 mls D.I. $H_2O$ | |
| U-Adapter (C) | | | |
| 5th Impinger GBS | | Empty | |
| U-Adapter (D) | | | |
| 6th Impinger Mod-GBS | | ~200 g Silica gel | |
| Gooseneck | | | |

Component changes during run:

Figure 5-2. Field Lab Set-up Data Sheet.

3. Rinse three times with deionized distilled water.

4. Rinse three times with acetone.

5. Rinse three times with hexane.

6. Air dry and seal to prevent contamination.

The blanks for all assembled trains were proof-rinsed prior to field use to verify cleanliness. See below for details of glassware proofing.

#### 5.1.1.4 Pretest Calibration of Equipment--

Prior to field testing, the Modified Method 5 (MM5) sampling equipment was calibrated. This equipment includes the dry gas meter, gas meter temperature instruments, nickle-plated nozzles, pitot tubes (S-type), barometer, and thermocouples used in conjunction with sampling. Pretest and posttest calibration data sheets are included in Appendix J. Procedures are noted in Appendix M-3.

#### 5.1.1.5 Proof Rinsing of Glassware--

Before any MM5 sampling took place, blank proof-rinsing of glassware for each fully assembled train was performed. The trains were assembled as if ready for field use, then were broken down as if a test were complete. The trains were then cleaned and rinsed by the appropriate methods (see Section 5.1.3, Sample Recovery). Sample components were set aside as samples for blank analysis.

### 5.1.2 Sample Train Operation

Sampling time for each run was intended to be a total of 4 h (240 min). However, plant malfunctions restricted sampling time for runs 1 and 3 to 160 and 190 min, respectively. PCDD/PCDF sampling was performed concurrently with particulate/metals sampling with train start/stop times between them varying by no more than a 5-min interval.

Leak checks on the probe/train assembly were performed prior to beginning each run, after the traverse of one port, prior to traversing a new port, and following the run. All leak checks conducted prior to a traverse were done at ≥ 15 in. $H_2O$ vacuum. Leak checks performed following a traverse were done at the highest vacuum encountered during the traverse. Acceptable limits for leak rates were established by EPA Method 5.

Both sampling locations required the use of three separate sampling ports (see Section 4.0, Sampling Locations, for schematic). Traverse lengths at both locations were 50 in. A total of 24 points were sampled at both locations, using 8-point traverses in each of the three ports. Sampling time was 10 min/point, with readings taken every 5 min. In all cases the inlet sampling train was operated with a cyclone and catch flask in place for removal of large particulates. The outlet train had a much lower particulate loading, allowing use of the cyclone bypass without a catch flask. Joints within all trains were greaseless; threaded glassware was used with Teflon ferrules for seal. Nickel nozzles were used at all times.

One set of semivolatile blank train samples was taken from both the inlet and outlet locations. The blank trains were assembled, taken to the appropriate location, leak-checked, and left idle (no heat or flow) at the sampling site for the same length of time as the normal train. The blank train was leak-checked again whenever the normal trains were leak-checked, thereby approximating the volume of ambient air taken in by the normal trains. Blank trains were recovered exactly as if they contained a sample.

### 5.1.3 Sample Recovery

Following each test, the sampling train and probe assembly were disconnected, and acetone-rinsed aluminum foil was placed over connections, preventing contamination or sample loss during transport to the field lab. A copy of the sample recovery data sheet is shown in Figure 5-3. Recovery of the probe was performed as follows:

1. Nozzle was removed and flask attached to probe outlet.
2. Nozzle was rinsed and brushed with acetone until clean.
3. Nozzle was rinsed and brushed with hexane.
4. Probe was rinsed and brushed with acetone into flask twice.
5. Clean flask was attached.
6. Probe was rinsed again and brushed with acetone. Probe inlet was sealed with Teflon-wrapped stopper or thumb. Probe was then tipped and acetone allowed to pass through its length several times. If acetone was dirty, flask was replaced and process repeated until clean. All rinses were saved as one sample.
7. Probe was rinsed and brushed into flask three times with hexane. Probe was tipped to allow hexane to pass through probe several times. An empty flask was used at the start of each rinse. All rinses were saved as one sample.

The heated flexible Teflon sample transfer lines were recovered in a manner identical to that of the probes.

MM5 semivolatile sample trains were recovered in the field lab according to the following procedure:

1. Each impinger was weighed and its weight recorded. The amount of condensate collected was calculated and given to personnel performing data reduction.
2. Amount of silica gel exhausted was documented.
3. Empty sample containers with labels and lids were weighed.

# MODIFIED METHOD 5 TRAIN
# SEMIVOLATILE ORGANICS SAMPLING
# FIELD LAB RECOVERY DATA

Project No. 8910 L (02-12)
Plant: Maine Energy Recovery Co., Biddeford, ME
Train was used for: ______________________
Run No. __________
Sampling Location: Unit A, ____________________
Sampling Train No. __________
Sample Box No. __________
Sample Box Recovery Date/Person ____________________
Nozzle/Probe/Sample Transfer Line Recovery Date/Persons ____________________

## BACK HALF RECOVERY

| Impinger | Condenser | XAD | 3rd | 4th | 5th | 6th | Condensate Collected (grams) |
|---|---|---|---|---|---|---|---|
| Final Wt.(g) | | | | | | | |
| Initial Wt.(g) | | | | | | | |
| Net Wt. (g) | | | | | | | |
| Description/ Color | | | | | | | |
| Sample Bottle Tare Wt. (g) | | | | | | | |
| Sample Number | | | | | | | |

Pour condensate in condenser outlet into XAD resin cartridge

| | | |
|---|---|---|
| Rinse Solvents | Acetone/<br>Hexane* | Acetone/<br>Hexane* |
| Components Rinsed: | Filter Support<br>Filter Holder Back<br>Short 90° Adapter<br>Condenser<br>T/C-well U-Adapter | 3rd,4th,5th Impingers<br>U-Adapters (A,B,C) |
| Sample Bottle Final Wt. (g) | | |
| Net Wt. (g) | | |

## FRONT HALF RECOVERY

| Component | Nozzle/Probe Glass Union Sample Transfer Line | Cyclone/Flask (loose contents) | Filter | Long 90° Adapter Cyclone/Flask Filter Holder Front |
|---|---|---|---|---|
| Sample Bottle Tare Wt. (g) | | | | |
| Sample Number | | | | |
| Rinse Solvents | Acetone/Hexane* | | | Acetone/Hexane* |
| Sample Bottle Final Wt. (g) | | | | |
| Net Wt. (g) | | | | |

* Acetone rinses (with Brushing) precede Hexane rinses.

Figure 5-3. Field Lab Recovery Data.

4. Sample numbers were entered on data sheets.

5. Sample train components were rinsed into appropriate sample containers according to format on data sheet.

6. pH was checked and adjusted with concentrated Baker Instra Analyzed nitric acid as necessary.

7. Full sample container with lid was weighed, allowing calculation of the net weight of sample. The reweighing of samples after shipment verified integrity of the sample.

8. Liquid levels were marked on each sample container, allowing a quick determination of leakage.

All samples (probe rinses and recovered train) were sealed, double-bagged, and stored in coolers with ice. The ice was checked periodically and during shipment to ensure proper storage conditions were maintained.

### 5.1.4 PCDD/PCDF Analysis

The analysis of all MM5 samples was performed in accordance with the draft ASME procedures,[4] with the exception of some minor changes normally made by MRI and used in previous projects. These are listed below, and no other deviations from the referenced protocol were necessary. Figures 5-4, 5-5, and 5-6 show sample extraction analysis schemes for PCDD/PCDF compounds.

1. All glassware was thoroughly detergent-washed, 5X rinsed in warm tap water, 3X rinsed with distilled water, rinsed with bulk acetone, air-dried, and stored until use. Immediately before use, all glassware was rinsed with high purity acetone followed with a 2X rinse with the solvent used in the method. Glassware blanks were collected and analyzed as appropriate.

2. Condensate and rinse samples from MM5 trains were extracted according to EPA Method 8280[5] but were analyzed according to the draft ASME procedure like the rest of the MM5 train samples.

3. The sample cleanup columns used were different from those specified in the ASME Method.[4] The columns were 1 x 10 cm columns packed with 1.0 g of silica gel and 4.0 g of 40% w/w sulfuric acid-modified silica gel; and 1 x 30 cm columns packed with 6.0 g of alumina covered with 1 cm of anhydrous sodium sulfate. The cleanup procedure and sorbent cleaning and preparation procedure are provided in Reference 6. In accordance with best professional judgment and good analytical techniques, a third and/or fourth column, according to the ASME protocol, or a performance equivalent, was utilized as necessary.

4. HRGC columns used by MRI for determination of all 2,3,7,8-substituted and total PCDD/PCDFs are 60-m DB-5 columns.

The above changes in the analysis method are considered to be minor. A brief summary of the referenced analysis method is presented below.[4]

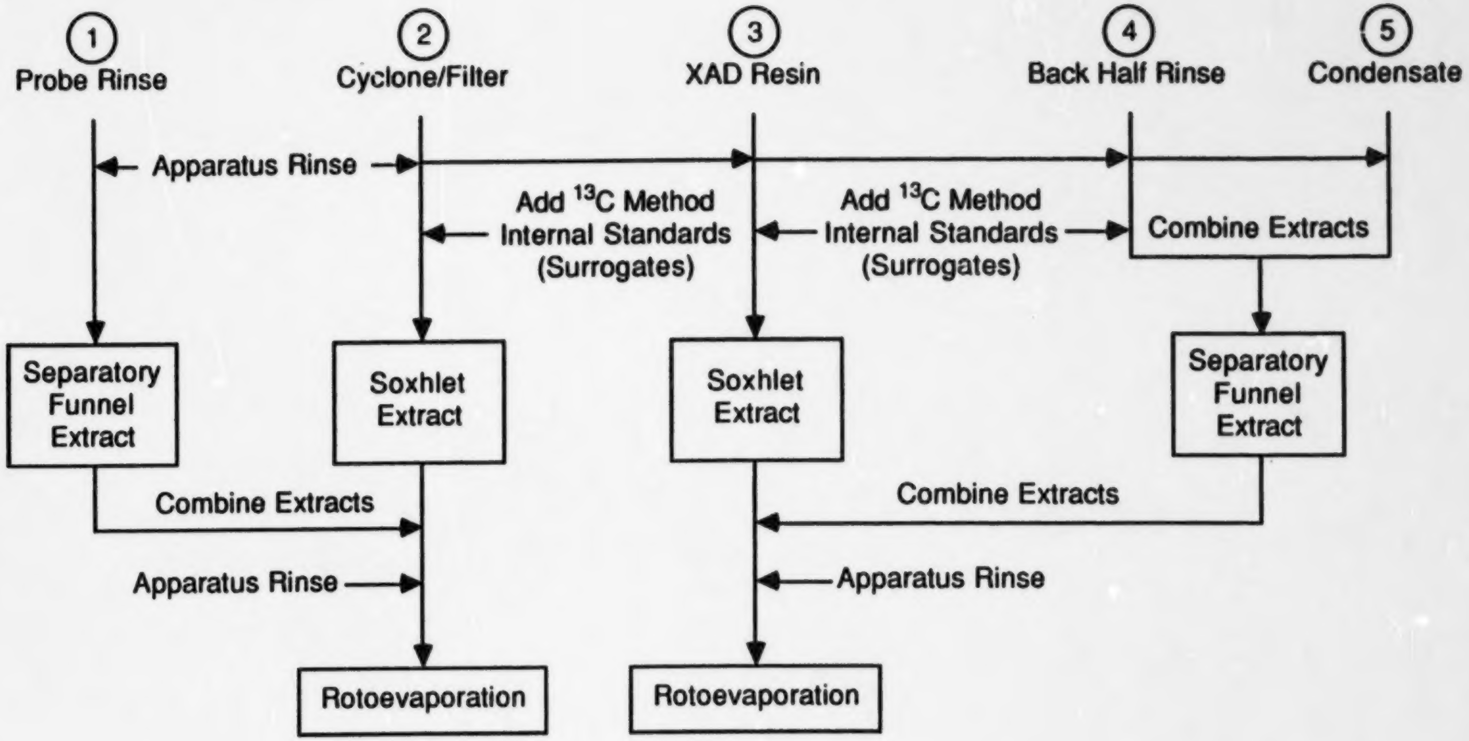

① Probe Rinse
② Cyclone/Filter
③ XAD Resin
④ Back Half Rinse
⑤ Condensate
Apparatus Rinse
Add $^{13}$C Method Internal Standards (Surrogates)
Add $^{13}$C Method Internal Standards (Surrogates)
Combine Extracts
Separatory Funnel Extract
Soxhlet Extract
Soxhlet Extract
Separatory Funnel Extract
Combine Extracts
Combine Extracts
Apparatus Rinse
Apparatus Rinse
Rotoevaporation
Rotoevaporation

Figure 5-4. Sample Extraction Scheme for Inlet MM5 Samples.

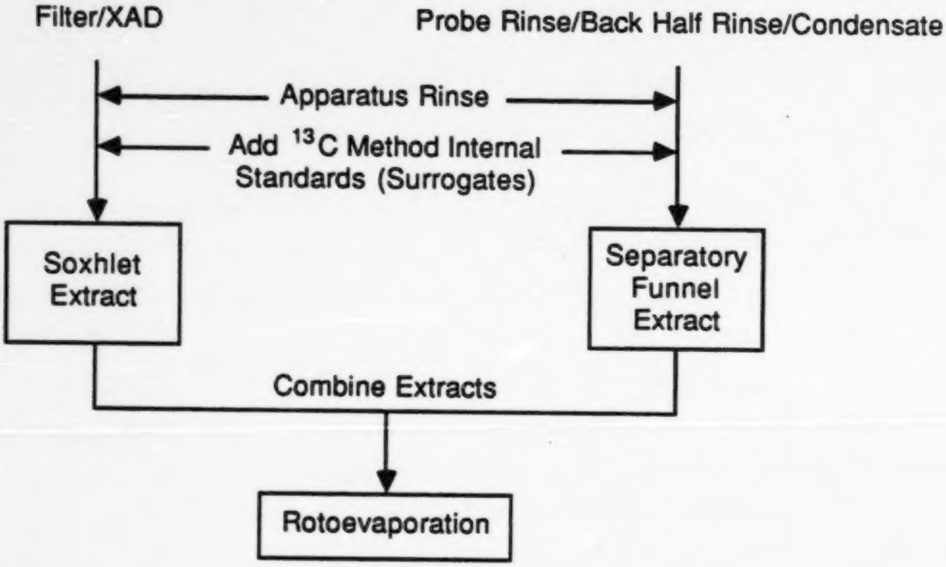
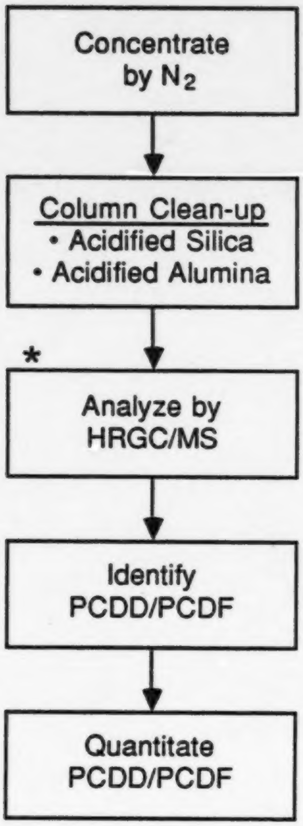

Filter/XAD
Probe Rinse/Back Half Rinse/Condensate
Apparatus Rinse
Add $^{13}C$ Method Internal Standards (Surrogates)
Soxhlet Extract
Separatory Funnel Extract
Combine Extracts
Rotoevaporation

Figure 5-5. Sample Extraction Scheme for Outlet and Blank MM5 Samples.


Concentrate by $N_2$
Column Clean-up
• Acidified Silica
• Acidified Alumina
*
Analyze by HRGC/MS
Identify PCDD/PCDF
Quantitate PCDD/PCDF

* = Add Recovery Internal Standards

Figure 5-6. Sample Cleanup and Analysis Scheme for PCDD/PCDF and Other Organics in the MM5 Train.

Each MM5 train composite sample is analyzed for the specified PCDD/PCDF. Prior to extraction, one component of each MM5 front-half and back-half sample fraction is spiked with the method internal standards. The MM5 components are extracted, composited, and concentrated by rotoevaporation. Each sample extract is cleaned up using the column cleanup techniques described below.

A 1 x 10 cm chromatography column is packed with 1.0 g of silica gel and 4.0 g of 40% w/w sulfuric acid-modified silica gel. A second chromatography column (1 x 30 cm) is packed with 6.0 g of alumina covered with 1 cm of anhydrous sodium sulfate. The silica gel (type 60, EM reagent, 100/120 mesh) and alumina (acid alumina, AG 4, Bio-RAD) are Soxhlet extracted with methylene chloride and activated at 130° and 190°C, respectively, before use. Each sample extract was added to the top of separate silica gel columns along with two 0.5-mL washes of the sample container. The columns are eluted with 45 mL of hexane directed onto the alumina columns. The alumina columns are eluted with an additional 20 mL of hexane, and the hexane is archived. The alumina columns are then eluted with 20 mL of 20% v/v methylene chloride/hexane. These samples are concentrated under nitrogen to about 1 mL, transferred to a 1-mL conical vial, and further evaporated just to dryness. Immediately prior to analysis, the sample residue is taken up in 23 µL of tridecane and the recovery internal standard is added.

The extracts were analyzed by high resolution gas chromatography/mass spectrometry with selected ion monitoring (HRGC/MS-SIM) using a 60 m x 0.25 mm DB-5 fused silica capillary column (FSCC). For analysis of all 2,3,7,8-substituted PCDD/PCDF extracts were analyzed using a 60 m x 0.25 mm DB-5 column. The mass spectrometer operated at 3000 resolution units.

The levels of dioxins and furans were calculated by comparison of the response of the samples to calibration standards. The response of the recovery internal standards was monitored from run to run for conformance to a 50% criterion envelope. Concentrations of each PCDD/PCDF congener were determined by comparison to the appropriate response factor determined from the calibration curve. Final concentrations are reported in units of ng/dscm.

### 5.1.5 GC/MS Data Reduction

The quantification of the samples was based on the internal standard method in which a constant amount of the recovery internal standard is added to all samples, blanks, and calibration standards just prior to analysis. The raw data for the quantification of the sample components consists of the computer-measured peak areas of the characteristic mass fragmentation ions of the method internal and recovery internal standards. The raw data are converted to concentrations by using mass spectrometric response factors relative to the internal standard.

If none of a target analyte was found, and thus could not be quantitated, the lower limit of detection is reported. This lower limit of detection is determined using the following steps:

1. A background area is determined by inspection of the GC/MS data.

2. Background area x 2.5 = lowest individual ion area that can be used to confirm the presence of the compound of interest.

3. Using the area in (2) and theoretical ion ratios, the minimum area that can be quantitated is determined.

4. The area from (3) is applied to the calculations to obtain the minimum concentration of the compound of interest that can be detected.

If a target analyte was found to be saturated, the sample was diluted, recovery internal standard added, and reanalyzed. The method internal standard recoveries and relative response factors were determined on the undiluted sample. The total amount of the analyte in the sample was determined using the following steps:

1. The unsaturated peaks from the original sample were entered onto a LOTUS 1-2-3 spreadsheet along with the method internal and recovery internal standards.

2. The original saturated peaks, which were on scale in the diluted sample, were entered onto a new LOTUS 1-2-3 spreadsheet with the recovery internal standard.

3. The amounts (ng) in both samples, undiluted and diluted, were then added together for the amount of analyte.

5.1.5.1 Determination of the Relative Response Factors (RRF)--

For initial calibration and certification of the GC/MS method, a minimum of three compound levels covering a significant portion of the linear range of the instrument was used to determine instrument sensitivity and linearity.

Ideally, the response factors are constant over the entire concentration range of interest. However, the response factors may vary with concentration. The relative response factor (RRF) is plotted against the area or peak height of the analytes in the calibration standards, using a minimum of three concentrations over the range of interest. The relative response factor is calculated according to the equation:

$$RRF = \frac{(As)(Cis)}{(Ais)(C_s)} \qquad \text{Eq. (1)}$$

where:

As = Area or peak height of the primary characteristic ion of the compound being quantified;

Cis = Concentration or amount of the recovery internal standard;

Ais = Area or peak height of the primary characteristic ion of the recovery internal standard; and

$C_s$ = Concentration or amount of the compound in the calibration standard.

### 5.1.5.2 Peak Identification--

Selected ion monitoring (SIM) was used to analyze the MM5 extracts for both qualitative and quantitative peak identification.

Qualitative peak identification refers to the peak eluted within the retention time windows set for that analyte. The sample spectrum is compared to that of a calibration standard. The intensity of the two largest ions in the molecular cluster must match the ratio observed for a standard within ±20%. System noise at low concentration or interferences may skew the ion ratio beyond the ±20% criteria. If the analyst's best judgment is that a peak that does not meet the qualitative criteria, i.e., is a match, the peak may be included in the calculation, with a footnote explaining the data and the reason for relaxing the criteria.

After a chromatographic peak is identified as a positive match, the compound is quantitated based either on the integrated abundance of the extracted ion current profile (EICP) or the SIM data for the primary characteristic ion in the appropriate tables listed in the analytical protocol. If interferences are observed for the primary ion, the secondary and tertiary ion are used for quantitation. For the ion used, the RRF is determined using that ion. The same criteria are applied to the internal standard compounds.

Primary, secondary, and tertiary ions are extracted from the reconstructed ion chromatograms. Ratio criteria for the ions must be met before the analyte is quantified.

In this study, quantification was based on the primary ion.

Following sample analysis, the appropriate response factor was taken from the calibration curve generated from Eq. (1) and the concentration of the compound in the sample calculated according to the equation:

$$\text{Sample Concentration} = \frac{(\text{As})(\text{Cis})}{(\text{Ais})(\text{RRF})} \qquad \text{Eq. (2)}$$

It is very important to determine the correct value for Cis, the concentration of the internal standard relative to the original sample matrix.

All of the peaks were summed for each analyte, and then those were summed to yield the total mass in the sample.* For a concentration-per-peak or concentration-per-analyte reporting format, each value is carried through the calculations appropriate manner.

### 5.1.6 Data Entry

Data transfer and reduction are essential functions in summarizing information to support conclusions. It is essential that these processes be performed accurately and, in the case of data reduction, accepted statistical techniques be used.

The entry of input data was a HP 110 portable computer which can utilize the LOTUS 1-2-3 spreadsheet software package.

At a minimum, example calculations must be included with the summarized data to facilitate review. The entry of input data and calculations should be checked and the signature/initials of the data technician and reviewer(s) accompany all data transfers with and without reduction.

### 5.1.7 GC/MS Data Validation

The principal criteria was used to validate the integrity of the GC/MS data acquired and reported during this program were the following:

1. Verification on a frequent basis by the analytical task leader that all raw data generated in the preceding week had been stored on magnetic tape and/or in hard copy and that storage locations were documented in the project records.

2. Examination of at least 5% of the raw data (e.g., chromatograms) on a daily basis by the organic analytical task leader to verify adequacy of documentation, confirm peak shape and resolution, assure that the computer was sensing peaks appropriately, etc.

3. Confirmation that raw areas for internal standards and calibration standards and raw and relative areas for surrogate compounds were within 50% of the expected value.

### 5.1.8 GC/MS Analytical Data

The quantification of the sample components was based on the internal standard method in which a constant amount of the internal standard is added to all samples, blanks, and calibration standards.

The raw data for the quantification of the sample components consisted of the computer-measured peak areas of the characteristic mass fragmentation ions of the internal standards and the analytes of interest. The raw data were converted to concentrations by using mass spectrometric response factors relative to the internal standard.

---

* A check must be made to ensure that the number of peaks measured does not exceed the theoretical maximum number of congeners for each isomeric group.

Concentrations of each PCDD/PCDF homolog were calculated by first calculating a response factor and then calculating a final concentration in nanograms per sample using the following equations (with TCDD as an example):

$$\text{Relative Response Factor (R.F.)} = \frac{A_{(std)}}{A_{(IS)}} \times \frac{C_{(IS)}}{C_{(std)}} \qquad \text{Eq. (3)}$$

where: $A_{(std)}$ = Area of ions m/z 320 and 322 for the unlabeled 2,3,7,8-TCDD in the standard;

$A_{(IS)}$ = Area of ions m/z 332 and 334 for the $^{13}C_{12}$-2,3,7,8-TCDD in the standard;

$C_{(IS)}$ = Concentration of $^{13}C_{12}$-2,3,7,8-TCDD in the standard (ng/mL); and

$C_{(std)}$ = Concentration of unlabeled 2,3,7,8-TCDD in the standard (ng/mL).

$$C_{(sample)} = \frac{A_{(sample)}}{A_{(IS)}} \times \frac{C_{(IS)}}{RF} \qquad \text{Eq. (4)}$$

where: $C_{(sample)}$ = Total concentration of all TCDD isomers in the sample (ng/sample);

$A_{(sample)}$ = Total area of ions m/z 320 and 322 for all TCDD isomers in the sample;

$A_{(IS)}$ = Area of ions m/z 332 and 334 for the $^{13}C_{12}$-2,3,7,8-TCDD in the sample; and

$C_{(IS)}$ = Concentration of $^{13}C_{12}$-2,3,7,8-TCDD in the sample (ng/mL).

The concentration of total TCDF is calculated with the above equations using the response of ions m/z 304 and 306 to measure the concentration of unlabeled TCDF and the response of ions m/z 316 and 318 for the $^{13}C_{12}$-2,3,7,8-TCDF. Similar procedures were used for each of the PCDD/PCDF homologs.

All data were qualified as "estimated" concentrations or tentative identifications, except where pure isomer standards were used to verify the results.

Recovery of method internal standards was monitored during analysis of samples. Target recovery values were 50% to 150% as outlined in the QA plan.

Recovery values were consistently low for all the method internal standards, ranging from 39% to 61% for all samples and compounds. Approximately 70% of all the method internal standard recoveries were within objectives (i.e., > 50%). When recovery limits for internal standards and precision limits were exceeded, the following actions were initiated:

1. The spiking procedure was checked, including the solution concentration, preparation, techniques, and calculations.

2. The archive and 50% methylene chloride/hexane fraction of the column cleanup procedure were concentrated and analyzed.

3. The data and spiking procedure was checked by a third person.

Monitoring for ion masses of possible furan interferents (chlorinated diphenyl ethers, CDPE) was completed for all samples (except duplicates) where a positive furan response was obtained. The CDPE compounds were monitored simultaneously with the PCDFs. Specifically, m/z 374 (HxDPE) was monitored vs. m/z 304 and 306 (TCDF); m/z 408 (HpDPE) vs. m/z 338 and 334 (PeCDF); m/z 444 (ODPE) vs. m/z 374 and 376 (HxCDF); m/z 478 (NDPE) vs. m/z 408 and 410 (HpCDF); and m/z 512 (DDPE) vs. m/z 442 and 444 (OCDF). These monitoring procedures are provided in Table 1 of the ASME analytical procedure.

By monitoring the PCDF ions and corresponding CDPE ions within a retention window, the presence of the possible interferents could be verified. Simultaneous responses for the specific PCDF homologs at the appropriate ratio and retention time and no response to the corresponding CDPE provided positive identification of the PCDF.

## 5.2 COMBUSTION GAS--PARTICULATE AND METALS SAMPLING AND ANALYSIS

The combustion gas sampling for particulate and metals analysis at the spray dryer inlet and the baghouse outlet was performed according to procedures specified in EPA Methods 1 through 5 and in Reference 7. This EMB metals protocol can be found in Appendix M. These procedures were followed except as discussed below where deviations from these methods and selected options in these methods as performed during the test program are described.

### 5.2.1 Equipment and Sampling Preparation

The combustion gas samples for metals and particulates were collected in the sampling train shown in Figure 5-7. Due to space restrictions at the spray dryer inlet, a flexible heat-traced Teflon sample transfer line connected the glass probe liner to the cyclone of the sampling train. The sample transfer line was not used, and a bypass replaced the cyclone in the train used at the baghouse outlet location. The sodium hydroxide impinger was used as an acid trap to protect downstream train components.

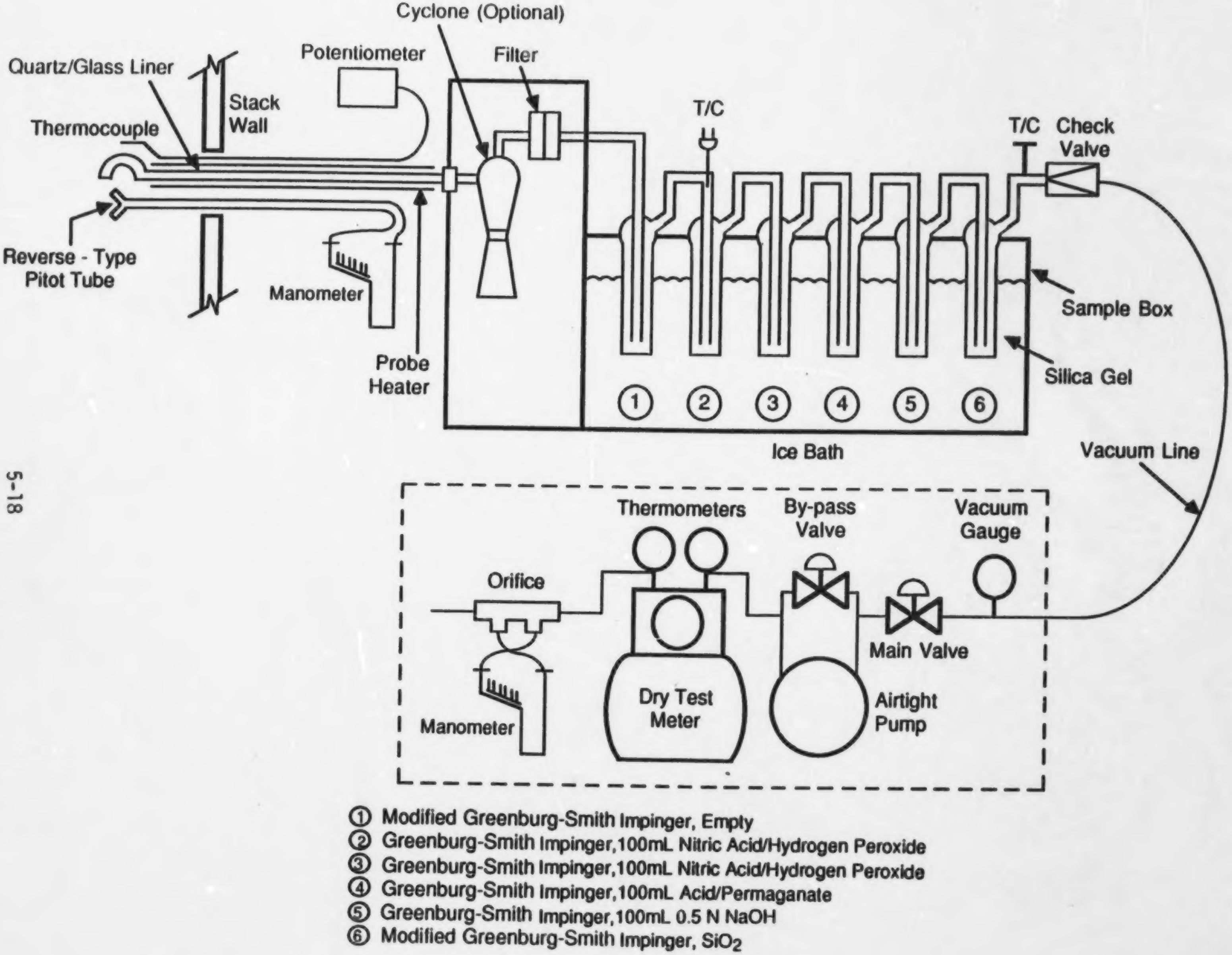

Cyclone (Optional)
Quartz/Glass Liner
Potentiometer
Filter
Stack Wall
Thermocouple
T/C
T/C
Check Valve
Reverse - Type Pitot Tube
Manometer
Probe Heater
Sample Box
Silica Gel
①
②
③
④
⑤
⑥
Ice Bath
Vacuum Line
Thermometers
By-pass Valve
Vacuum Gauge
Orifice
Main Valve
Dry Test Meter
Airtight Pump
Manometer
① Modified Greenburg-Smith Impinger, Empty
② Greenburg-Smith Impinger,100mL Nitric Acid/Hydrogen Peroxide
③ Greenburg-Smith Impinger,100mL Nitric Acid/Hydrogen Peroxide
④ Greenburg-Smith Impinger,100mL Acid/Permaganate
⑤ Greenburg-Smith Impinger,100mL 0.5 N NaOH
⑥ Modified Greenburg-Smith Impinger, SiO2

Figure 5-7. Modified Method 5 Sampling Train for Particulates and Metals.

All sampling nozzles were made of nickel. These nozzles were used because nickel was not one of the target metals. The nozzles were not rinsed with acid during sample recovery. A list of other equipment used specifically for this test program may be found in Table J-2 in Appendix J.

Each train component and piece of glassware was individually identified with a component number recorded on the field lab set-up data sheet before each use. This prevented the accidental exchange of components among the trains. Three trains were set up to be used for one purpose throughout the test program: inlet train, the outlet train, and a blank train used at both the inlet and outlet during two of the sampling runs.

### 5.2.2 Sampling Train Operation

Samples were extracted for 10 min at each of the 24 sampling points during a complete run (run 2) or until the run had to be stopped because of process problems (runs 1 and 3). Sampling and combustion gas data were recorded every 5 min during each run. Sampling was conducted according to U.S. EPA Method 5 with appropriate modifications as necessary to accommodate the two sampling locations. Leak checks were performed at the beginning and end of each run and before and after each port and train component change.

Static pressure determinations were made several times during each run, and the results were averaged and used in the final calculations for combustion gas volumetric flow rates and the isokinetic sampling rates for both trains used at each location. A concurrent velocity head reading and total pressure reading (impact tip of pitot) were recorded. A U-tube manometer connected to the impact pitot line was used to measure total pressure. The velocity pressure was obtained by multiplying the velocity head by the squared pitot tube coefficient. The static pressure was obtained by subtracting the velocity pressure from the total pressure.

### 5.2.3 Sample Recovery

After a sampling run, each train was disassembled into sections (probe, sample transfer line, sample box) before being transferred to the field lab. The nozzles were sealed with plastic cap plugs and the probe outlets were sealed with glass blank-offs. The ends of each sample transfer line were connected with the glass union that had connected the line to the probe liner. The sample box inlet was covered with aluminum foil that did not contact any sample surface.

Certain apparatuses, i.e., probe flasks and brushes, used for recovery were designated for use on only one train to prevent cross-contamination of samples. All sample containers had preprinted, computer-generated labels. Replicates of each label were used to (a) identify the sample container, (b) identify sample container over-wrap, and (c) verify recovery by entry into the field laboratory log book. The sample identification logs are in Appendix K.

The nozzles were removed from the probes and brushed and rinsed with acetone until clean. Each probe was brushed and rinsed with acetone at least three times or until clean into a flask attached to one end. The flask was replaced, and the probe was rinsed again by passing acetone back and forth through the probe several times to remove any residual particulate. The sample transfer lines were recovered in the same manner, and all probe/nozzle/sample transfer line acetone rinses from each train were combined as one sample.

The probe liners and sample transfer lines were then rinsed three times with 0.1 N nitric acid. A brush was not used, and the nozzles were not rinsed with acid. The acid rinses for each train were combined and saved as one sample from each train.

The probe liners and sample transfer lines were rinsed again with acetone, which was discarded.

After removal of the filter and the loose cyclone/flask catch, the front half of the filter holders and the remaining front half components in the sample box were brushed and rinsed with acetone until particulate recovery was complete. The same components were then rinsed with 0.1 N nitric acid at least three times. The acetone and acid rinses were saved as separate samples.

The amount of condensate collected in the impingers was determined by weight change of the impingers after each run and was used to determine the moisture content of the gas samples. The impinger solutions were recovered as specified in the EMB metals protocol.[7] The impinger containing sodium hydroxide was rinsed with deionized water.

All samples were stored in coolers containing bagged ice before and during shipment to the analytical laboratory. The samples were then placed in a refrigerated room to await analysis.

### 5.2.4 Particulate Analysis

All samples for particulate analysis were checked for leakage and loss during shipment by examining the liquid level marks on the containers. No losses occurred. The acetone samples were weighed and transferred to tared glass beakers. The sample containers were rinsed into the beakers with weighed amounts of acetone. The acetone was evaporated at about 70°F (room temperature) and ambient pressure. The acetone residues and the combined filter/cyclone catches were desiccated at ambient temperature and pressure, and they were weighed to a constant weight as defined in Method 5. Acetone and filter blanks were treated in the same manner. Figure 5-8 illustrates the sequence of sample fraction analyses.

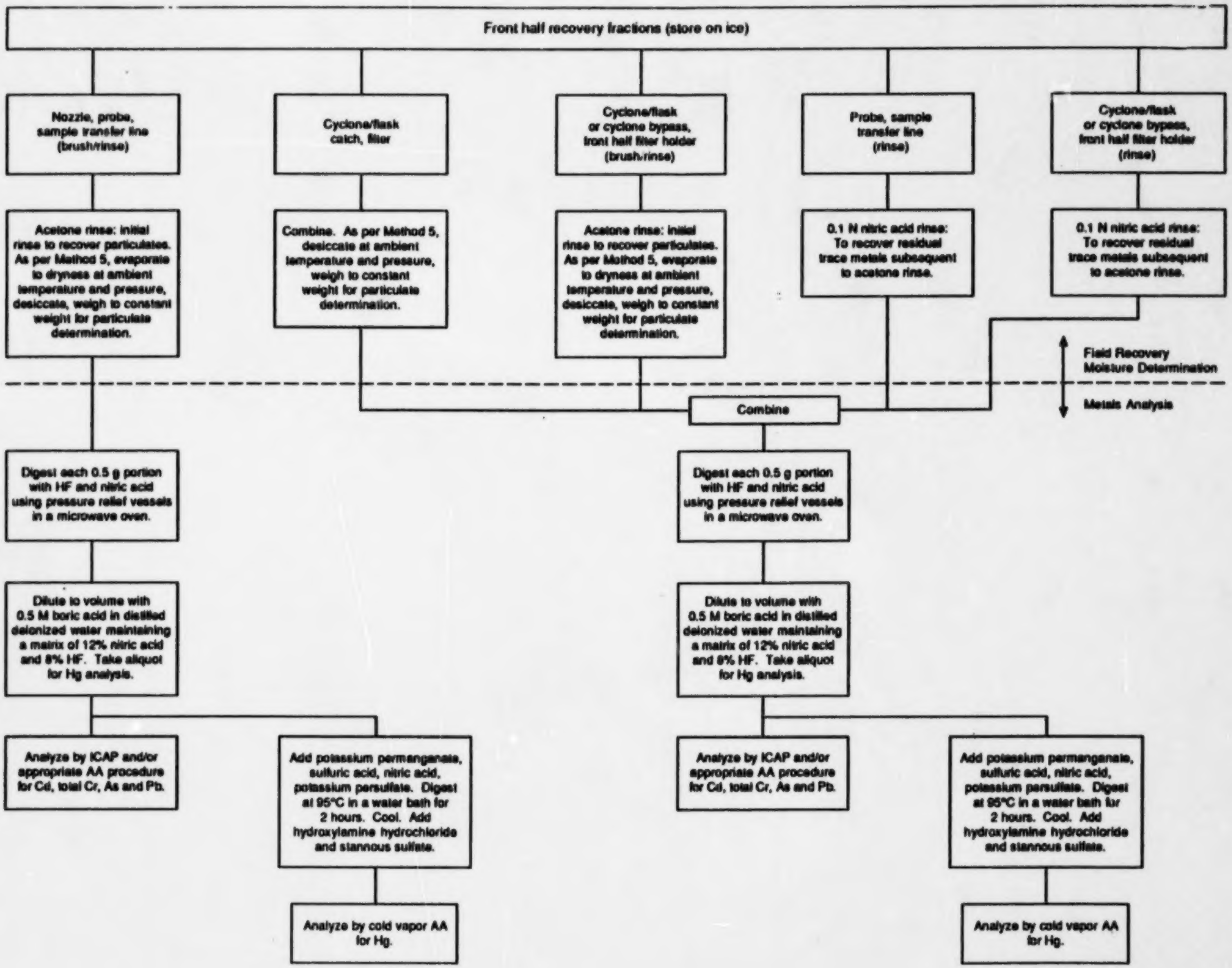

Front half recovery fractions (store on ice)
Nozzle, probe, sample transfer line (brush/rinse)
Cyclone/flask catch, filter
Cyclone/flask or cyclone bypass, front half filter holder (brush/rinse)
Probe, sample transfer line (rinse)
Cyclone/flask or cyclone bypass, front half filter holder (rinse)
Acetone rinse: initial rinse to recover particulates. As per Method 5, evaporate to dryness at ambient temperature and pressure, desiccate, weigh to constant weight for particulate determination.
Combine. As per Method 5, desiccate at ambient temperature and pressure, weigh to constant weight for particulate determination.
Acetone rinse: initial rinse to recover particulates. As per Method 5, evaporate to dryness at ambient temperature and pressure, desiccate, weigh to constant weight for particulate determination.
0.1 N nitric acid rinse: To recover residual trace metals subsequent to acetone rinse.
0.1 N nitric acid rinse: To recover residual trace metals subsequent to acetone rinse.
Field Recovery Moisture Determination
Metals Analysis
Combine
Digest each 0.5 g portion with HF and nitric acid using pressure relief vessels in a microwave oven.
Digest each 0.5 g portion with HF and nitric acid using pressure relief vessels in a microwave oven.
Dilute to volume with 0.5 M boric acid in distilled deionized water maintaining a matrix of 12% nitric acid and 8% HF. Take aliquot for Hg analysis.
Dilute to volume with 0.5 M boric acid in distilled deionized water maintaining a matrix of 12% nitric acid and 8% HF. Take aliquot for Hg analysis.
Analyze by ICAP and/or appropriate AA procedure for Cd, total Cr, As and Pb.
Add potassium permanganate, sulfuric acid, nitric acid, potassium persulfate. Digest at 95°C in a water bath for 2 hours. Cool. Add hydroxylamine hydrochloride and stannous sulfate.
Analyze by ICAP and/or appropriate AA procedure for Cd, total Cr, As and Pb.
Add potassium permanganate, sulfuric acid, nitric acid, potassium persulfate. Digest at 95°C in a water bath for 2 hours. Cool. Add hydroxylamine hydrochloride and stannous sulfate.
Analyze by cold vapor AA for Hg.
Analyze by cold vapor AA for Hg.

Figure 5-8. MERC Facility Particulate/Metals MM5 Train Field Recovery and Analytical Protocol.

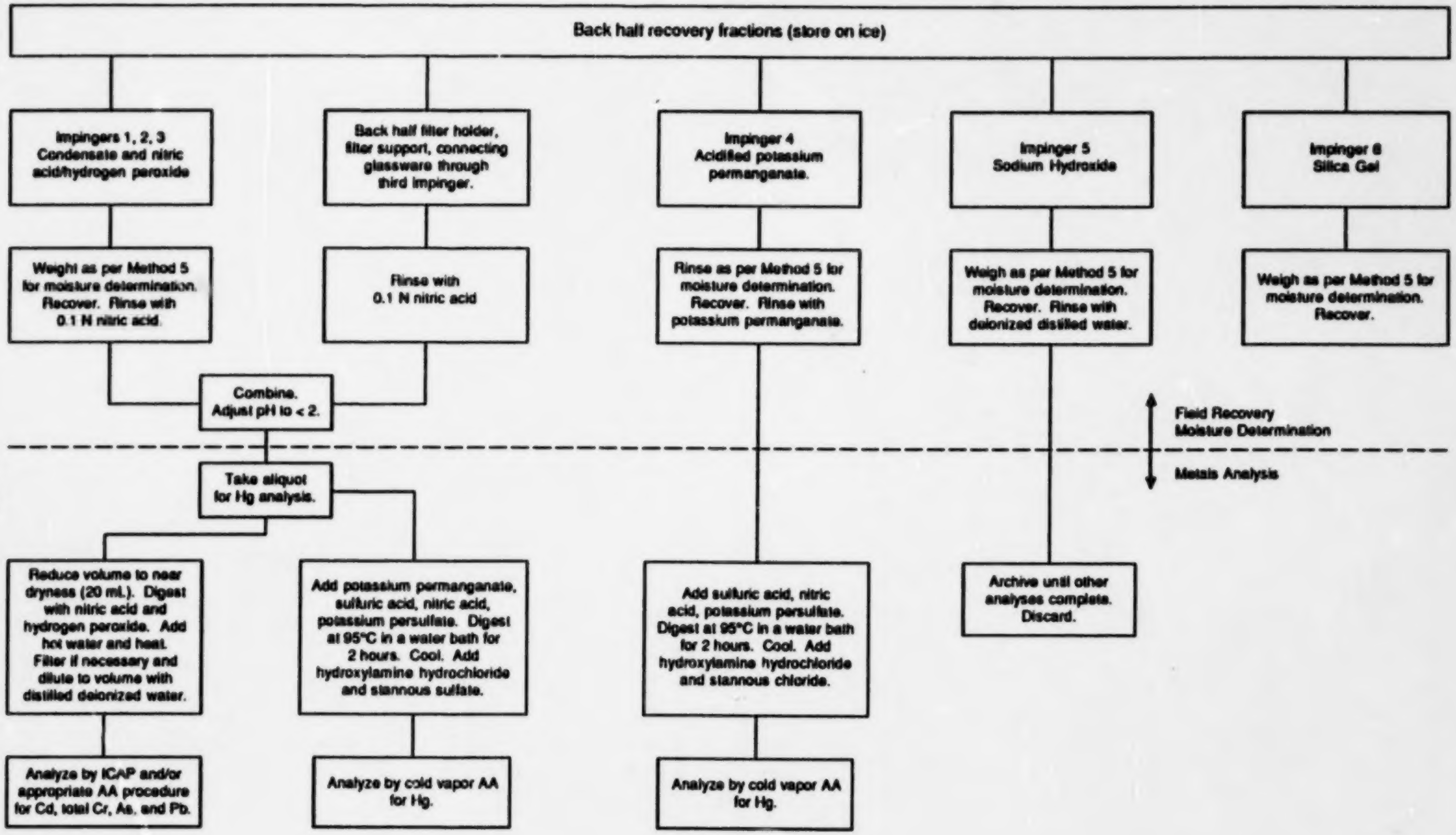

Back half recovery fractions (store on ice)
Impingers 1, 2, 3 Condensate and nitric acid/hydrogen peroxide
Back half filter holder, filter support, connecting glassware through third impinger.
Impinger 4 Acidified potassium permanganate.
Impinger 5 Sodium Hydroxide
Impinger 6 Silica Gel
Weight as per Method 5 for moisture determination. Recover. Rinse with 0.1 N nitric acid.
Rinse with 0.1 N nitric acid
Rinse as per Method 5 for moisture determination. Recover. Rinse with potassium permanganate.
Weigh as per Method 5 for moisture determination. Recover. Rinse with deionized distilled water.
Weigh as per Method 5 for moisture determination. Recover.
Combine. Adjust pH to < 2.
Field Recovery Moisture Determination
Metals Analysis
Take aliquot for Hg analysis.
Reduce volume to near dryness (20 mL). Digest with nitric acid and hydrogen peroxide. Add hot water and heat. Filter if necessary and dilute to volume with distilled deionized water.
Add potassium permanganate, sulfuric acid, nitric acid, potassium persulfate. Digest at 95°C in a water bath for 2 hours. Cool. Add hydroxylamine hydrochloride and stannous sulfate.
Add sulfuric acid, nitric acid, potassium persulfate. Digest at 95°C in a water bath for 2 hours. Cool. Add hydroxylamine hydrochloride and stannous chloride.
Archive until other analyses complete. Discard.
Analyze by ICAP and/or appropriate AA procedure for Cd, total Cr, As, and Pb.
Analyze by cold vapor AA for Hg.
Analyze by cold vapor AA for Hg.

Figure 5-8. (Continued)

### 5.2.5 Metals Analysis

All front half sample fractions underwent a microwave digestion procedure employing a CEM Corporation microwave digestion system with hydrofluoric acid and nitric acid as the digestion matrix. The digestates were diluted to volume with 0.5 M boric acid to reduce the destructive capabilities of the hydrofluoric acid on analytical instrument components.

An aliquot of each of the digestates was taken and analyzed for mercury by cold vapor atomic absorption spectroscopy according to SW-846,[5] Method 7470. The balance of the digestates was analyzed for cadmium, total chromium, lead, and arsenic by inductively coupled argon plasma atomic emission spectroscopy (ICAP) according to SW-846, Method 6010. Where necessary, graphite furnace atomic absorption spectroscopy was used to analyze for lead and arsenic according to SW-846, Methods 7421 and 7060, respectively.

The combined condensate and nitric acid impinger fraction was digested according to SW-846, Method 3050. An aliquot of the digestate was removed for mercury analysis by Method 7470. The balance of the digestate was analyzed for cadmium, total chromium, lead, and arsenic by Method 6010. Where necessary, Methods 7421 and 7060 were used to analyze for lead and arsenic, respectively.

The acidified potassium permanganate impinger fraction was analyzed for mercury according to Method 7470. The sodium hydroxide impinger fraction was not analyzed. Figure 5-8 illustrates the sequence of the sample fraction analyses.

### 5.2.6 Data Reduction

The particulate loading was calculated with the following equations.

Mass of particulate collected:

$$m_n = (m_p - m_b)_{\text{filter/cyclone}} + (m_p - m_b)_{\text{acetone rinses}} \qquad \text{Eq. (5)}$$

$m_n$ = Mass of particulate collected from source (g)

$m_p$ = Gross mass of particulate (g)

$m_b$ = Mass of particulate in blanks (g)

Particulate concentration (actual):

$$C = (0.001 \text{ g/mg}) \; (m_n / V_{m(std)}) \qquad \text{Eq. (6)}$$

C = particulate loading (mg/dscm)

$V_{m(std)}$ = volume of dry gas sampled corrected to standard conditions (dscm @ 1 atm and 68°F)

Particulate concentration (corrected to 12% $CO_2$):

$$C_N = C(12/CO_2) \qquad \text{Eq. (7)}$$

$C_N$ = particulate concentration (mg/dscm), corrected to 12% $CO_2$

$CO_2$ = percent by volume of $CO_2$ in combustion gas, dry-basis

Particulate mass emission rate:

$$M = C\ Q_{std}\ (60\ \text{min./h})\ (10^{-6}\ \text{kg/mg}) \qquad \text{Eq. (8)}$$

M = particulate mass emission rate (kg/h)

$Q_{std}$ = combustion gas volumetric flow rate on dry basis at standard conditions 68°F, 1 atm ($m^3$/min.)

Metal analyte concentration:

$$C_{metal} = (C_o - C_b)/V_{m(std)} \qquad \text{Eq. (9)}$$

$C_{metal}$ = metal concentration in combustion gas (µg/dscm)

$C_o$ = mass of metal detected in sample (µg)

$C_b$ = mass of metal detected in blank (µg)

$V_{m(std)}$ = volume of dry gas sampled corrected to standard conditions (dscm @ 1 atm and 68°F)

## 5.3 ASH, LIME SLURRY, AND RDF SAMPLING AND ANALYSIS

Five different types of grab samples were collected at the test site: cyclone ash, baghouse discharge ash, bottom ash, RDF, and lime slurry. All samples requiring a separate analysis (i.e., organics vs. metals) were split in the field and placed in an appropriately prepared and marked sample container.

Grab sample collection typically began 40 to 60 min after start of the test, with grabs being taken about every hour thereafter. Final samples were collected about 1 h after the completion of a test. The exception to this was the lime slurry, which was sampled only once each test period, 2 h into the run.

### 5.3.1 Cyclone Ash

#### 5.3.1.1 Sampling--

Cyclone ash was sampled through a 5-cm (2-in.) gate valve located on the bottom side of an inclined cylindrical chute connecting the cyclone to the ash conveyor system. The sampling procedure consisted of opening the sample port, clearing the sample port with a steel rod to ensure against bridging, and collecting sample in a 5-gal. steel pail. Following the test, the ash was mixed for homogenization and placed in the appropriate sample jars.

On several occasions very little cyclone ash was available for sampling. In these cases, any sample obtained was still mixed in and split evenly among the appropriate containers.

### 5.3.1.2 Analysis--

Analysis for percent combustibles and percent carbon was performed by Galbraith Laboratories. Percent combustibles analysis followed ASTM Method E777 using a Leco CR-12 IR detector. Percent carbon analysis followed ASTM Method D 3174.

### 5.3.1.3 PCDD/PCDF--

Samples for organics analysis were extracted with benzene, with the extract currently archived at the MERC plant location.

### 5.3.1.4 Metals--

The sample was prepared for analysis by digestion with microwave digestion procedure using a CEM Corporation microwave digestion system with hydrofluoric acid and nitric acid as the digestion matrix. The digestates were diluted to volume with 0.05 M boric acid to reduce the destructive capabilities of the hydrofluoric acid on analytical instrument components.

The analyses performed followed SW-846[5] Methods 6010 (ICAP), 7421 (lead furnace), 7060 (arsenic furnace), and 7470 (mercury cold vapor), with method modifications as detailed in Appendix H-2.

## 5.3.2 Baghouse Discharge Ash

### 5.3.2.1 Sampling--

Baghouse discharge ash was collected from a 5-cm (2-in.) gate valve placed on the bottom side of a conveyor roughly 3.5 m (10 ft) downstream from the baghouse discharge. A 19-L (5-gal.) steel pail was placed beneath the port for sample collection. Following each run, the sample was homogenized (mixed) and split into appropriate containers for each analysis.

In addition to the samples collected above, two 19-L (5-gal.) pails double-lined with polyethylene bags were filled with baghouse discharge ash. These samples were turned over to EPA personnel for further analysis.

### 5.3.2.2 Analysis--

Analysis for percent combustibles and percent carbon was performed by Galbraith Laboratories. The percent combustibles analysis performed followed ASTM Method E777 using a Leco CR-12 IR detector. Percent carbon analysis followed ASTM Method D 3174.

### 5.3.2.3 PCDD/PCDF--

Baghouse discharge ash samples were extracted with benzene. The extracts are currently archived at the MERC plant location.

### 5.3.2.4 Metals--

The sample was prepared for analysis by digestion with microwave digestion procedure using a CEM Corporation microwave digestion system with hydrofluoric acid and nitric acid as the digestion matrix. The digestates were diluted to volume with 0.05 M boric acid to reduce the destructive capabilities of the hydrofluoric acid on analytical instrument components.

The analyses performed followed SW-846[5] Methods 6010 (ICAP), 7421 (lead furnace), 7060 (arsenic furnace), and 7470 (mercury cold vapor), with method modifications as detailed in Appendix H-2.

#### 5.3.2.5 Resistivity--

Resistivity of baghouse discharge ash was determined by Southern Research Institute using Method IEEE 548-1984. The samples were tested at a constant humidity of 14.8% water vapor by volume. Results, included in Appendix I, show maximum ash resistivity over the 325° to 390°F temperature range.

### 5.3.3 Bottom Ash

#### 5.3.3.1 Sampling--

Bottom ash samples were taken from a conveyor that carries the ash from the quench tank to a disposal area. As with other ash samples, individual aliquots were mixed for homogenization and then split into the appropriate sample containers. Due to problems with the process, EPA requested that no run 3 bottom ash sample be collected.

#### 5.3.3.2 Analysis--

Analysis for percent combustibles and percent carbon was performed by Galbraith Laboratories. Percent combustibles analysis followed ASTM Method E777 using a Leco CR-12 IR detector. Percent carbon analysis followed ASTM Method D 3174.

#### 5.3.3.3 PCDD/PCDF--

Bottom ash samples collected for organics analysis were extracted with benzene. The extracts are currently archived at the MERC plant location.

#### 5.3.3.4 Metals--

The sample was prepared for analysis by digestion with microwave digestion procedure using a CEM Corporation microwave digestion system with hydrofluoric acid and nitric acid as the digestion matrix. The digestates were diluted to volume with 0.05 M boric acid to reduce the destructive capabilities of the hydrofluoric acid on analytical instrument components.

The analyses performed followed SW-846[5] Methods 6010 (ICAP), 7421 (lead furnace), 7060 (arsenic furnace), and 7470 (mercury cold vapor), with method modifications as detailed in Appendix H-2.

### 5.3.4 Lime Slurry

#### 5.3.4.1 Sampling--

Lime slurry samples were taken from the feed line at the top of the spray dryer. Prior to collection of each sample, the line was purged into a bucket. Each grab consisted of three samples: one each for organics analysis, metals analysis, and physical properties analysis. One grab was collected for each run, approximately 2 h into the test.

#### 5.3.4.2 Analysis--

Percent lime, percent solids, and specific gravity analyses of the lime slurry samples were performed by Galbraith Laboratories.

#### 5.3.4.3 Metals--

The sample was prepared for analysis by digestion with microwave digestion procedure using a CEM Corporation microwave digestion system with hydrofluoric acid and nitric acid as the digestion matrix. The digestates were diluted to volume with 0.05 M boric acid to reduce the destructive capabilities of the hydrofluoric acid on analytical instrument components.

The analyses performed followed SW-846[5] Methods 6010 (ICAP), 7421 (lead furnace), 7060 (arsenic furnace), and 7470 (mercury cold vapor), with method modifications as detailed in Appendix H-2.

### 5.3.5 Refuse Derived Fuel

#### 5.3.5.1 Sampling--

RDF composite samples for run 1 were collected at the beginning of the long transfer conveyor belt which feeds into the plant's ram loading system. A grain shovel was used for sampling a chute that feeds RDF onto the conveyor belt; one shovelful was collected each grab. Samples were stored in a fiber drum lined with double plastic bags.

Runs 2 and 3 RDF composite samples were obtained at the ram feed on boiler A. A 19-L (5-gal.) pail was lowered by rope into the ram feed and allowed to fill. The full pail was emptied into a fiber drum lined with double plastic bags.

#### 5.3.5.2 Analysis--

Following completion of the test program, all RDF samples were turned over to EPA personnel for storage and analysis.

## 5.4 CONTINUOUS GAS ANALYZERS

Three sets of MRI CEMs were used to monitor gaseous emissions from the incinerator. Oxygen and carbon dioxide were measured at all three locations. $SO_2$ was monitored at the spray dryer inlet and baghouse outlet. THC and CO were measured at the spray dryer inlet, and $NO_x$ was measured at the baghouse outlet. Each analyzer system was leak checked from the probe before and after each test. All analyzers were also zeroed and spanned before and after each test. The average of both calibrations was used to calculate the final concentrations. All calibration gases were introduced at the inlet to the conditioning manifold. The data loggers corrected the CO and $CO_2$ analyzer outputs for nonlinearity. The current $CO_2$ concentration was used to correct the CO readings for the loss of $CO_2$ through the Ascarite scrubber. All data were logged continuously with 1-min averages.

The accuracy of the working standard calibration gases was checked by comparing them against EPA protocol no. 1 cylinders at the end of one test day. Due to time constraints, the protocol cylinders could not be recertified before the test. Instead, the protocol cylinders were returned to the vendor for recertification after the test. Since some of the span cylinders were changed during the test, the various span cylinders were also included in the comparative checks. Cylinder accuracy results and analyzer calibration data are presented in Section 6.0.

A schematic of the equipment used at the spray dryer inlet is shown in Figure 5-9. Table 5-2 is the detailed equipment list. Figure 5-10 and Table 5-3 provide similar details for the spray dryer outlet. Figure 5-11 and Table 5-4 describe the equipment used at the baghouse outlet. HCl was also measured by Entropy Environmentalists under a separate EPA contract. Details of their equipment can be found in Reference 2.

## 5.5 CARBON DIOXIDE AND OXYGEN SAMPLING AND ANALYSIS BY EPA METHOD 3

Carbon dioxide and oxygen determinations were made during the three sampling runs to obtain data for calculating the molecular weight of the combustion gas and for adjusting pollutant concentration and emission results to a standard excess air volume, i.e., 12% $CO_2$ or 7% $O_2$. The procedures used during this test program are contained in MRI's SOP S-4 (see Appendix M) and are consistent with EPA Method 3.

Sample extraction was performed at a constant rate during the course of the particulate/metals MM5 train sampling at the spray dryer inlet and the baghouse outlet locations. Integrated multipoint sampling was accomplished with a stainless steel tube attached to the MM5 probe so that samples would be extracted near the same points used for particulate/metals samples. Flue gas analysis was done with an Orsat analyzer. The sampling data and analysis results are in Appendix D.

For each traverse at a port (10 min at each of eight points for the MM5 train), the first sampling point was the point farthest from the port. The integrated gas sampling train was purged with combustion gas for approximately 5 min before sampling commenced. Sampling was discontinued as a precaution at the point nearest the port to avoid dilution of the sample from any in-leakage through the port seal. Although in-leakage was minimized by the seals, a slight amount of in-leakage could have occurred from time to time because of the very negative pressure in the ducts. Concurrent temperature readings did indicate, however, that any in-leakage would have been minimal. As a result, the integrated gas sampling concurred with 85% to 95% of the MM5 sampling.

The inlet tip of the stainless steel tube was positioned approximately 3 in. behind the components (nozzle and pitot tube) of the MM5 probe tip to prevent flow interference. The tube tip was in the area that would have been affected by in-leakage during sampling at the points closest to the ports. More than the minimum number of points required by EPA Method 3 were sampled. The sampling point matrix approximated that required by EPA Method 1 for 21 points and was sufficient to obtain reliable results for carbon dioxide and oxygen concentrations during the three sampling runs.

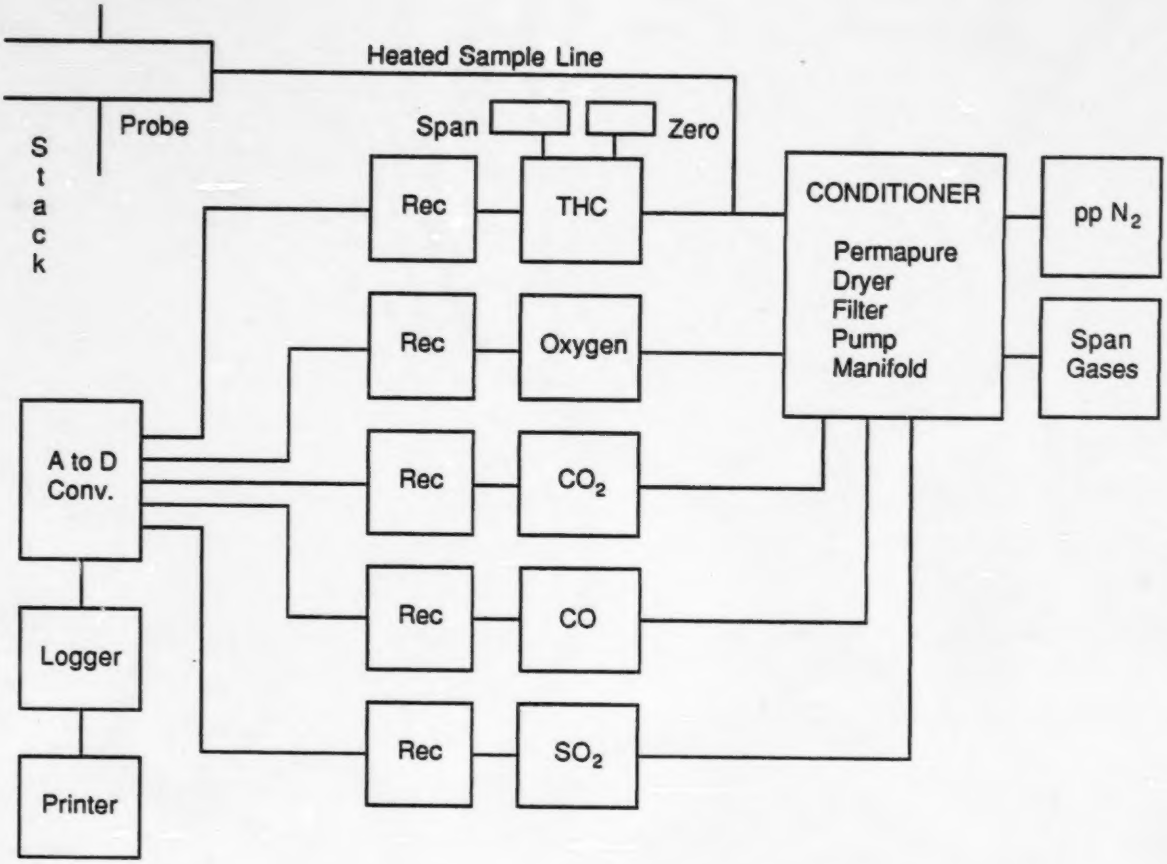

Heated Sample Line
Probe
Stack
Span
Zero
Rec
THC
CONDITIONER
Permapure
Dryer
Filter
Pump
Manifold
pp $N_2$
Rec
Oxygen
Span Gases
A to D Conv.
Rec
$CO_2$
Rec
CO
Logger
Rec
$SO_2$
Printer

Figure 5-9. Schematic of Spray Dryer Inlet CEM Equipment.

## TABLE 5-2. CEM EQUIPMENT USED AT SPRAY DRYER INLET

| | |
|---|---|
| Probe | Sintered Inconel, 50 mm by 500 mm, 3-μm pore size. |
| Sampling line | Technical Heaters model LP212-5, electrically heated Teflon tubing operated at 120°C (248°F). |
| Conditioner | MRI built with Permapure filter/coalescer and extractive dryer, Teflon diaphragm pump and capillary flow splitters to each analyzer. All parts before dryer are heated to > 120°C (248°F). Flow controls, sample line blowback and pressure/vacuum gauges are included. Zero and span gases are introduced at conditioner inlet. |
| Zero gas | Prepurified nitrogen from high pressure cylinder, the nitrogen supply is also used for the dryer module as the drying gas and to blow back the sample line. |
| Span gases | Detailed list is in Appendix J. |
| THC analyzer | Beckman model 402, heated oven flame ionization detector. Has built-in zero and span controls. |
| Oxygen analyzer | Horiba model PMA 200, paramagnetic sensor. |
| Carbon dioxide analyzer | Horiba model PIR 2000S, nondispersive infrared. |
| Carbon monoxide analyzer | Horiba model PIR 2000L, nondispersive infrared. The analyzer inlet has an ascarite/silica gel cartridge to prevent the $CO_2$ interference. |
| Sulfur dioxide analyzer | Whitacre model P310, electrochemical sensor. |
| Recorders | Heath model SR 204 strip chart recorders. Used for backup to the data logger. |
| A to D converter | MRI built system based on Wintek MCS control modules with 12 bit analog to digital resolution and RS-232 host computer interface. |
| Data logger | Zenith model Z-181 portable PC with GWBASIC logging program. |
| Printer | Okidata model 182 printer to record all logger operations. |

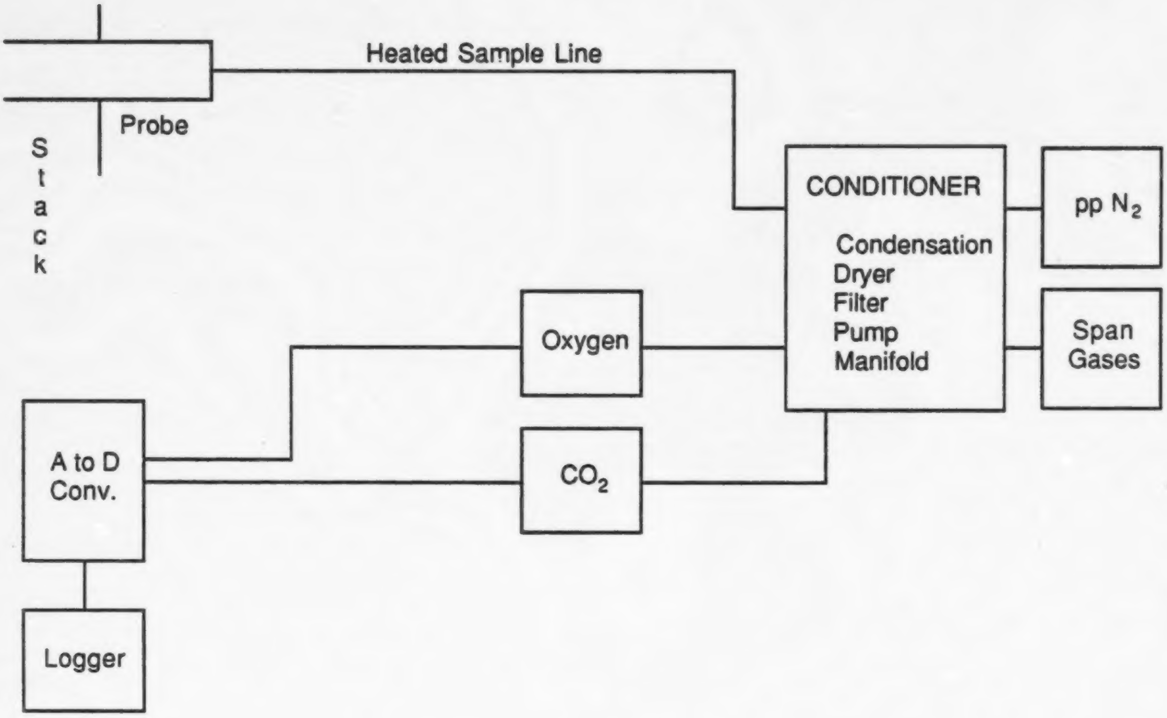

Heated Sample Line
Probe
Stack
CONDITIONER
Condensation
Dryer
Filter
Pump
Manifold
pp $N_2$
Span Gases
Oxygen
$CO_2$
A to D Conv.
Logger

Figure 5-10. Schematic of Spray Dryer Outlet CEM Equipment.

## TABLE 5-3. CEM EQUIPMENT USED AT SPRAY DRYER OUTLET

| | |
|---|---|
| Probe | Permapure model F-500-625-12 sintered stainless steel, self-cleaning bypass type with 5-μm pore size. |
| Sampling line | Technical Heaters model LP212-5, electrically heated Teflon tubing operated at 120°C (248°F). |
| Conditioner | MRI built with Permapure filter, water condensate trap, Teflon diaphragm pump, and flow controls for each analyzer. Zero and span gases are introduced at conditioner inlet. |
| Zero gas | Prepurified nitrogen from high pressure cylinder. |
| Span gases | Detailed list is in Appendix J. |
| Oxygen analyzer | Beckman model 7003, polarographic sensor. |
| Carbon dioxide analyzer | Horiba model PIR 2000S, nondispersive infrared. |
| A to D converter | MRI built system based on Wintek MCS control modules with 12 bit analog to digital resolution and RS-232 host computer interface. |
| Data logger | Epson model HX-20 portable computer with GWBASIC logging program. |

Computer has built-in printer.

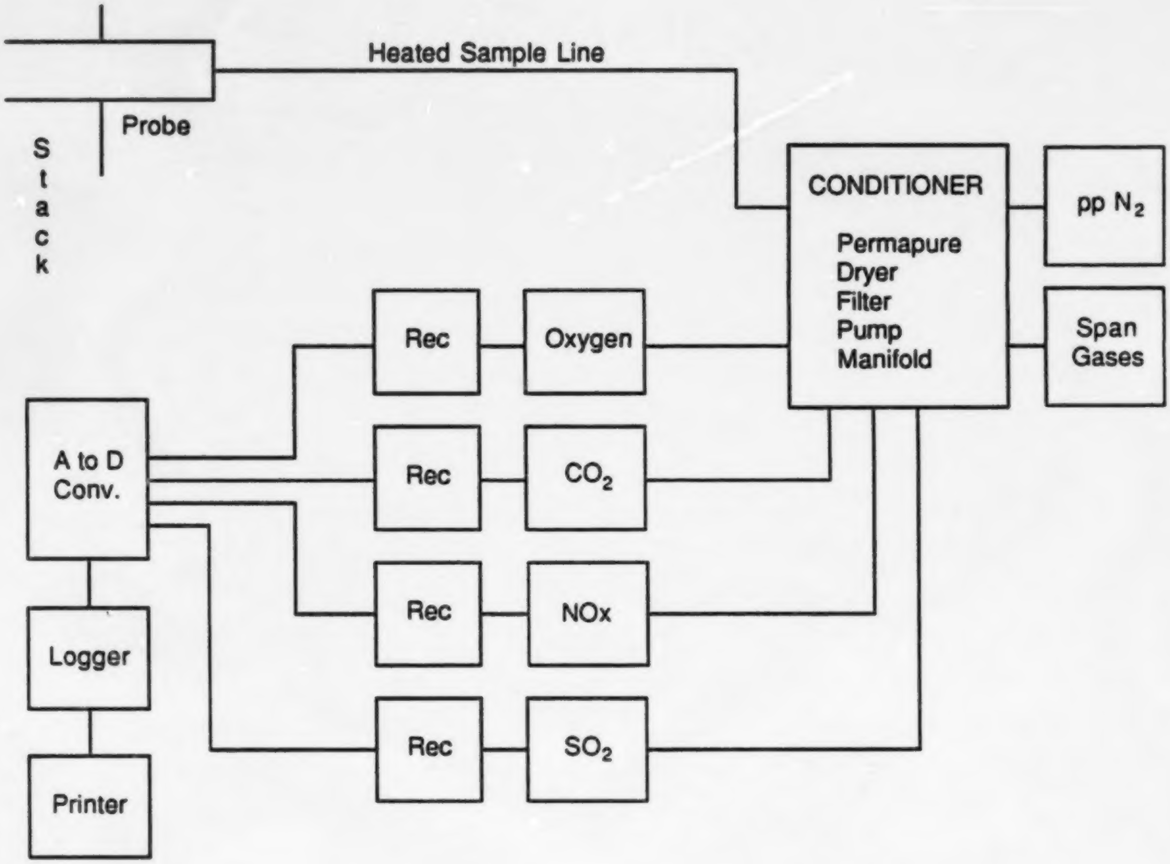

Heated Sample Line
Probe
Stack
CONDITIONER
Permapure
Dryer
Filter
Pump
Manifold
pp $N_2$
Span Gases
Rec
Oxygen
Rec
$CO_2$
Rec
NOx
Rec
$SO_2$
A to D Conv.
Logger
Printer

Figure 5-11. Schematic of Baghouse Outlet CEM Equipment.

## TABLE 5-4. CEM EQUIPMENT USED AT BAGHOUSE OUTLET

| | |
|---|---|
| Probe | Sintered stainless steel, 50 mm by 500 mm, 3-μm pore size. |
| Sampling line | Technical Heaters model LP212-5, electrically heated Teflon tubing operated at 120°C (248°F). |
| Conditioner | MRI built with Permapure filter/coalescer and extractive dryer, Teflon diaphragm pump, and flow splitters to each analyzer. All parts before dryer are heated to > 120°C (248°C). Flow controls, sample line blowback, and pressure/vacuum gauges are included. Zero and span gases are introduced at conditioner inlet. |
| Zero gas | Prepurified nitrogen from high pressure cylinder, the nitrogen supply is also used for the dryer module as the drying gas and to blow back the sample line. |
| Span gases | Detailed list is in Appendix J. |
| Oxygen analyzer | Beckman model 742, polarographic sensor. |
| Carbon dioxide analyzer | Horiba model PIR 2000S, nondispersive infrared. |
| Nitrogen oxides analyzer | Bendix model 8101-B, chemiluminescence detector. The conditioning manifold includes a nitrogen dilution system to maintain a constant dilution factor for both calibration and sample gases. |
| Sulfur dioxide analyzer | Whitacre model P310, electrochemical sensor. |
| Recorders | Heath model SR 204 and Soltec model 1243 strip chart recorders. Used for backup to the data logger. |
| A to D converter | MRI built system based on Wintek MCS control modules with 12 bit analog to digital resolution and RS-232 host computer interface. |
| Data logger | Zenith model Z-181 portable PC with GWBASIC logging program. |
| Printer | Okidata model 182 printer to record all logger operations. |

During the first sampling run at the baghouse outlet, the diaphragm pump in the integrated gas sampling train leaked. This leakage was not obvious during the leak checks before and after the sampling run, but it was discovered after the Orsat analysis from both the inlet and outlet locations were compared. The leak was corrected and an additional leak check procedure was employed. With the probe tip plugged and the train operating at a vacuum greater than the sampling vacuum, the end of the tube that was connected to the gas sample bag was submerged in water and observed for at least 1 min. If no bubbling was observed, there was no leak.

# SECTION 6.0

# QA/QC

## 6.1 INTRODUCTION

This section describes activities performed by project personnel as part of internal quality control (QC) functions, as well as the quality assurance (QA) audits and reviews that were conducted independently of the project team by MRI Quality Assurance Coordinators. This section also includes a summary of field and laboratory technical systems audits conducted by EPA and Research Triangle Institute (RTI). Copies of the audit reports are included in Appendix L.

Tests performed at the MERC facility and the subsequent analysis and reporting of results were performed under the direction of the Project Leader, Dr. George Scheil. Field tests and sampling were coordinated by the Field Sampling Task Leader, Mr. James Surman. Metals and organic analyses were performed under the supervision of Ms. Eileen McClendon and Dr. John Coates, respectively.

QA activities were performed under the direction of Mr. Dennis Hooton, Quality Assurance Coordinator (QAC) for the Environmental Systems Department. All QA reports and corrective actions were reported to department and project management and to Ms. Carol Green, Quality Assurance Manager for MRI.

## 6.2 SUMMARY OF QC DATA

Summaries and discussions of QC data for the various analyses are presented below.

### 6.2.1 Dioxin/Furan Analyses

6.2.1.1 Method Internal Standard Surrogate Recoveries--
Each sample analyzed for dioxins and furans was spiked with $^{13}$C-PCDD/PCDF method internal standards to determine surrogate recoveries and to quantitate native PCDD/PCDF compounds.

Recovery values for the method internal standards were consistently low, ranging from 30% to 70% for all surrogates in the field samples and audit samples (spiked XAD and water). Approximately 70% of all the method internal standard recoveries for the field samples were within the QAPP objective (i.e., > 50% recovered). Although these generally low surrogate recovery values were investigated by the technical staff, no conclusive explanation was identified other than possibly a procedural loss of compounds (e.g., in the column cleanup step). This theory is supported by the consistency of the low recoveries from the extracted samples, the high recoveries in the (nonextracted) instrument performance sample, and the highly accurate results for native PCDD/PCDF in the audit samples.

The impact of the low recoveries on sample data appears minimal because the calculation of native PCDD/PCDF is not dependent on absolute recovery of the surrogates. The accuracy of the quantitation method is supported by the results of the spiked performance audit samples (PAS) which had similar surrogate recovery values (see Appendix L for PAS quantitation reports), but were well within the QA objective of 50% to 150% accuracy for spiked native PCDD/PCDF. Performance audit sample results are discussed in detail later in this section.

Complete results of the surrogate recovery values are in the quantitation summary tables presented in Appendix G of this report. A summary of the reported surrogate recoveries is presented in Table 6-1.

#### 6.2.1.2 GC/MS Calibration Checks for PCDD/PCDF Analyses--

The response factor comparison tables for total and specific tetra-octa CDD/CDF are found in Tables 6-2 and 6-3, respectively. These tables include the response factors of the daily calibration standards compared with the average response factors of the calibration standard curve. This is used to check the calibration drift of the mass spectrometer. The computer-generated spreadsheets for the calibration curve and daily standards along with the Mass Spectrometry Notebook are found in Appendix L.

Variability of response factors were less than ±20% RSD for all PCDD/PCDF compounds during initial calibration; 99% for all continuing calibration checks were also within the ±20% RSD criteria during analyses of samples.

#### 6.2.1.3 PCDD/PCDF Blank Data--

Three types of blanks were collected from the uncontrolled and controlled locations: proof blanks, field blanks, and post blanks. Only the controlled blanks were analyzed.

Trace levels of octa-CDD, relatively close to the detection limit, were found in all three of the blanks. Trace levels of TCDD, also relatively close to the detection limit, were reported for the proof and post blanks, and were attributed to possible laboratory contamination. Based on technical review by project analysts, it was concluded that the amounts of analytes found in the blanks are relatively low and would not have a significant impact on sample results.

Complete results for the blank samples are found in Appendix L of this report. A summary of the blank results is presented in Table 6-4.

TABLE 6-1. DIOXIN/FURAN SURROGATE RECOVERIES FOR FIELD AND QC SAMPLES FOR MERC MWC

| | $^{13}$C-TCDD | $^{13}$C-PeCDD | $^{13}$C-HxCDD | $^{13}$C-HpCDD | $^{13}$C-OCDD | $^{13}$C-TCDF | $^{13}$C-PeCDF | $^{13}$C-HxCDF | $^{13}$C-HpCDF |
|---|---|---|---|---|---|---|---|---|---|
| Blanks | | | | | | | | | |
| Proof | 46.5 | 50.3 | 55.4 | 48.9 | 50.3 | 47.1 | 50.2 | 57.8 | 54.2 |
| Field | 46.4 | 50.3 | 60.0 | 55.9 | 56.9 | 50.1 | 55.4 | 62.5 | 59.0 |
| Post | 52.3 | 54.0 | 59.1 | 55.6 | 52.9 | 54.2 | 56.0 | 65.0 | 57.6 |
| EPA audits | | | | | | | | | |
| 130 | 51.0 | 58.9 | 57.6 | 63.7 | 67.8 | 55.6 | 63.4 | 60.0 | 60.8 |
| 145 | 54.8 | 59.7 | 59.8 | 61.2 | 63.7 | 53.9 | 61.5 | 64.4 | 59.4 |
| 176 | 44.9 | 49.8 | 61.8 | 63.6 | 65.5 | 47.7 | 52.2 | 65.8 | 64.4 |
| QA samples | | | | | | | | | |
| Performance sample | 83.3 | 97.4 | 84.7 | 86.7 | 90.0 | 89.7 | 100.9 | 87.9 | 86.6 |
| Spiked filter | 48.7 | 53.7 | 58.0 | 60.6 | 64.1 | 46.1 | 42.7 | 46.9 | 49.8 |
| Blank filter | 46.4 | 57.6 | 58.1 | 61.7 | 60.1 | 46.8 | 56.9 | 56.8 | 57.4 |
| Spiked XAD | 59.3 | 63.1 | 69.2 | 72.0 | 72.7 | 60.3 | 66.8 | 70.7 | 68.1 |
| Blank XAD | 55.9 | 58.4 | 69.2 | 66.4 | 65.1 | 54.5 | 65.5 | 67.7 | 68.2 |
| Spiked XAD/filter | 44.6 | 54.5 | 62.2 | 59.7 | 58.9 | 50.7 | 54.8 | 64.1 | 60.0 |
| Blank XAD/filter | 42.2 | 53.1 | 59.9 | 62.4 | 64.0 | 48.3 | 56.6 | 60.1 | 60.9 |
| Spiked water | 30.2 | 37.0 | 57.7 | 50.7 | 44.3 | 41.8 | 44.6 | 59.2 | 61.1 |
| Blank water | 57.6 | 59.5 | 59.6 | 62.3 | 66.3 | 48.5 | 61.2 | 61.4 | 60.8 |
| Uncontrolled | | | | | | | | | |
| Run 1 | | | | | | | | | |
| FH | 46.9 | 58.9 | 54.5 | 61.0 | 60.6 | 50.7 | 58.1 | 60.3 | 56.0 |
| BH | 43.5 | 45.5 | 56.8 | 52.9 | 48.4 | 46.0 | 49.2 | 58.1 | 54.1 |
| Run 2 | | | | | | | | | |
| FH | 48.1 | 57.9 | 54.7 | 59.4 | 52.3 | 54.3 | 48.3 | 57.3 | 55.3 |
| BH | 56.9 | 53.7 | 58.7 | 56.1 | 52.9 | 52.2 | 54.3 | 61.0 | 58.1 |
| Run 3 | | | | | | | | | |
| FH | 46.1 | 54.9 | 51.3 | 52.2 | 56.2 | 46.5 | 54.7 | 52.0 | 51.1 |
| BH | 59.4 | 55.3 | 56.0 | 56.1 | 53.1 | 48.2 | 55.9 | 60.3 | 57.2 |

(continued)

TABLE 6-1 (continued)

| | $^{13}$C-TCDD | $^{13}$C-PeCDD | $^{13}$C-HxCDD | $^{13}$C-HpCDD | $^{13}$C-OCDD | $^{13}$C-TCDF | $^{13}$C-PeCDF | $^{13}$C-HxCDF | $^{13}$C-HpCDF |
|---|---|---|---|---|---|---|---|---|---|
| Controlled | | | | | | | | | |
| Run 1 | 45.8 | 47.2 | 52.6 | 50.1 | 48.3 | 47.7 | 49.9 | 55.2 | 51.4 |
| Run 1 dup. | 45.1 | 48.0 | 50.8 | 50.1 | 50.0 | 44.5 | 48.2 | 53.5 | 50.4 |
| Run 2 | 39.4 | 43.7 | 49.5 | 47.4 | 44.8 | 39.2 | 47.0 | 55.7 | 48.0 |
| Run 3 | 58.8 | 56.1 | 57.9 | 53.3 | 52.9 | 51.2 | 55.0 | 59.0 | 55.0 |

$^{13}$C-TCDD is used in calculating total TCDD and 2,3,7,8-TCDD.

$^{13}$C-PeCDD is used in calculating total PeCDD and 1,2,3,7,8-PeCDD.

$^{13}$C-HxCDD is used in calculating total HxCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, and 1,2,3,7,8,9-HxCDD.

$^{13}$C-HpCDD is used in calculating total HpCDD and 1,2,3,4,6,7,8-HpCDD.

$^{13}$C-OCDD is used in calculating total OCDD and total OCDF.

$^{13}$C-TCDF is used in calculating total TCDF and 2,3,7,8-TCDF.

$^{13}$C-PeCDF is used in calculating total PeCDF, 1,2,3,4,8-PeCDF, 1,2,3,7,8-PeCDF, and 2,3,4,7,8-PeCDF.

$^{13}$C-HxCDP is used in calculating total HxCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6,7,8-HxCDF, 1,2,3,4,7,9,-HxCDF, 2,3,4,6,7,8-HxCDF, and 1,2,3,7,8,9-HxCDF.

$^{13}$C-HpCDF is used in calculating total HpCDF, 1,2,3,4,6,7,8-HpCDF, and 1,2,3,4,7,8,9-HpCDF.

TABLE 6-2. RESPONSE FACTOR COMPARISON TABLE FOR TOTAL TETRA-OCTA CDD/CDF

Response Factor (RRF) • [Area(S)/Area(IS)] • [Conc.(IS)/Conc.(S)]

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date analyzed: | | | | | 1/29/88 | 1/30/88 | 1/30/88 | 1/31/88 | 1/31/88 | 3/18/88 | 3/18/88 |
| Standard conc.: | 1/28/88 | | | | DF100 | DF100 | DF100 | DF100 | DF100 | DF100 | DF100 |
| Data file no.: | Average | | Range | Range | A29XQ6 | A30XQ2 | A30XQ3 | A31XQ2 | A31XQ3 | C18XQ6 | C18XQ7 |
| Area R.I.S 1: | response | % RSD | (RRF) | (RRF) | 804768 | 608768 | 956800 | 800192 | 841816 | 1016270 | 1084380 |
| Area R.I.S 2: | factor | (RRF) | -20% | +20% | 1557430 | 1172410 | 1947610 | 1512190 | 1472290 | 1888120 | 2514200 |
| $^{13}$C-1,2,3,4-TCDD | 1.000 | 0.00 | 0.800 | 1.200 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| $^{13}$C-1,2,3,7,8,9-HxCDD | 1.000 | 0.00 | 0.800 | 1.200 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| $^{13}$C-2,3,7,8-TCDF | 1.934 | 10.63 | 1.547 | 2.320 | 1.932 | 1.818 | 1.845 | 1.753 | 1.805 | 1.864 | 1.958 |
| $^{13}$C-1,2,3,7,8-PeCDF | 1.521 | 14.97 | 1.217 | 1.825 | 1.852 | 1.663 | 1.790 | 1.743 | 1.555 | 1.361 | 1.620 |
| $^{13}$C-1,2,3,6,7,8-HxCDF | 1.480 | 6.49 | 1.184 | 1.776 | 1.501 | 1.578 | 1.534 | 1.500 | 1.515 | 1.500 | 1.420 |
| $^{13}$C-1,2,3,4,6,7,8-HpCDF | 1.011 | 3.57 | 0.809 | 1.214 | 1.013 | 1.038 | 0.999 | 0.992 | 1.026 | 1.029 | 1.072 |
| $^{13}$C-2,3,7,8-TCDD | 1.354 | 12.54 | 1.083 | 1.625 | 1.319 | 1.319 | 1.339 | 1.371 | 1.350 | 1.204 | 1.376 |
| $^{13}$C-1,2,3,7,8-PeCDD | 0.778 | 11.91 | 0.622 | 0.933 | 0.849 | 0.841 | 0.927 | 0.908 | 0.781 | 0.796 | 0.881 |
| $^{13}$C-1,2,3,6,7,8-HxCDD | 0.940 | 2.23 | 0.752 | 1.129 | 0.937 | 0.971 | 0.923 | 0.954 | 0.940 | 0.993 | 0.915 |
| $^{13}$C-1,2,3,4,6,7,8-HpCDD | 0.624 | 3.95 | 0.499 | 0.748 | 0.630 | 0.672 | 0.666 | 0.599 | 0.657 | 0.634 | 0.654 |
| $^{13}$C-OCDD | 0.605 | 11.65 | 0.484 | 0.725 | 0.617 | 0.698 | 0.709 | 0.537 | 0.654 | 0.714 | 0.781[a] |
| Total tetra-CDF | 2.594 | 9.50 | 2.075 | 3.113 | 2.643 | 2.636 | 2.622 | 2.681 | 2.701 | 2.724 | 2.605 |
| Total penta-CDF | 2.273 | 15.37 | 1.818 | 2.727 | 1.967 | 2.166 | 2.084 | 2.174 | 2.185 | 2.485 | 2.320 |
| Total hexa-CDF | 2.238 | 6.61 | 1.791 | 2.686 | 2.144 | 2.069 | 2.039 | 2.121 | 2.110 | 2.146 | 2.214 |
| Total hepta-CDF | 2.383 | 4.18 | 1.906 | 2.859 | 2.397 | 2.384 | 2.396 | 2.335 | 2.395 | 2.265 | 2.276 |
| Octa-CDF | 2.192 | 1.12 | 1.753 | 2.630 | 2.131 | 2.109 | 1.936 | 2.109 | 2.158 | 1.985 | 2.025 |
| Total tetra-CDD | 2.367 | 6.71 | 1.893 | 2.840 | 2.498 | 2.508 | 2.412 | 2.702 | 2.343 | 2.828 | 2.388 |
| Total penta-CDD | 2.914 | 3.05 | 2.331 | 3.496 | 3.006 | 2.925 | 2.768 | 2.870 | 2.986 | 2.882 | 2.859 |
| Total hexa-CDD | 2.325 | 12.57 | 1.860 | 2.790 | 2.623 | 2.640 | 2.611 | 2.505 | 2.450 | 2.488 | 2.666 |
| Total hepta-CDD | 3.036 | 5.61 | 2.429 | 3.644 | 3.016 | 2.996 | 2.972 | 3.048 | 3.007 | 3.022 | 3.094 |
| Octa-CDD | 2.044 | 5.66 | 1.635 | 2.453 | 2.009 | 1.999 | 1.907 | 2.022 | 2.016 | 1.880 | 1.900 |

[a] Outside ±20% RSD from average RRF.

TABLE 6-3. RESPONSE FACTOR COMPARISON TABLE FOR SPECIFIC TETRA-OCTA CDD/CDF

Response Factor (RRF) = [Area(S)/Area(IS)] • [Conc.(IS)/Conc.(S)]

| Date analyzed:<br>Standard conc.:<br>Data file no.:<br>Area R.I.S 1:<br>Area R.I.S 2: | 1/28/88 Average response factor | % RSD (RRF) | Range (RRF) -20% | Range (RRF) +20% | 1/29/88<br>DF100<br>A29XQ6<br>804768<br>1557430 | 1/30/88<br>DF100<br>A30XQ2<br>608768<br>1172410 | 1/30/88<br>DF100<br>A30XQ3<br>956800<br>1947610 | 1/31/88<br>DF100<br>A31XQ2<br>800192<br>1512190 | 1/31/88<br>DF100<br>A31XQ3<br>841816<br>1472290 | 3/18/88<br>DF100<br>C18XQ6<br>1016270<br>1888120 | 3/18/88<br>DF100<br>C18XQ7<br>1084380<br>2514200 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,3,7,8-Tetra-CDF | 2.594 | 9.50 | 2.075 | 3.113 | 2.643 | 2.560 | 2.622 | 2.681 | 2.701 | 2.724 | 2.605 |
| 1,2,3,4,8-Penta-CDF | 2.362 | 10.36 | 1.890 | 2.835 | 2.186 | 2.241 | 2.281 | 2.228 | 2.225 | 2.620 | 2.395 |
| 1,2,3,7,8-Penta-CDF | 1.988 | 18.49 | 1.590 | 2.385 | 1.620 | 1.812 | 1.739 | 1.834 | 1.875 | 2.046 | 1.898 |
| 2,3,4,7,8-Penta-CDF | 2.272 | 15.32 | 1.817 | 2.726 | 1.967 | 2.166 | 2.084 | 2.174 | 2.185 | 2.485 | 2.320 |
| 1,2,3,4,7,8-Hexa-CDF | 2.327 | 6.88 | 1.862 | 2.793 | 2.284 | 2.156 | 2.164 | 2.282 | 2.261 | 2.215 | 2.390 |
| 1,2,3,6,7,8-Hexa-CDF | 2.537 | 6.82 | 2.029 | 3.044 | 2.452 | 2.314 | 2.392 | 2.446 | 2.434 | 2.522 | 2.519 |
| 1,2,3,4,7,9-Hexa-CDF | 1.527 | 5.10 | 1.222 | 1.833 | 1.477 | 1.436 | 1.362 | 1.352 | 1.319 | 1.442 | 1.499 |
| 2,3,4,6,7,8-Hexa-CDF | 2.238 | 6.61 | 1.791 | 2.686 | 2.144 | 2.069 | 2.039 | 2.121 | 2.110 | 2.146 | 2.214 |
| 1,2,3,7,8,9-Hexa-CDF | 2.045 | 9.03 | 1.636 | 2.455 | 1.923 | 1.852 | 1.825 | 1.979 | 1.958 | 1.890 | 1.918 |
| 1,2,3,4,6,7,8-Hepta-CDF | 2.383 | 4.18 | 1.906 | 2.859 | 2.397 | 2.384 | 2.396 | 2.335 | 2.395 | 2.265 | 2.276 |
| 1,2,3,4,7,8,9-Hepta-CDF | 2.095 | 4.03 | 1.676 | 2.514 | 2.124 | 2.068 | 2.204 | 1.914 | 2.071 | 1.932 | 2.020 |
| Octa-CDF | 2.192 | 1.12 | 1.753 | 2.630 | 2.131 | 2.109 | 1.936 | 2.109 | 2.158 | 1.985 | 2.025 |
| 2,3,7,8-TCDD | 2.367 | 6.71 | 1.894 | 2.841 | 2.498 | 2.508 | 2.412 | 2.702 | 2.343 | 2.828 | 2.388 |
| 1,2,3,7,8-Penta-CDD | 2.914 | 3.05 | 2.331 | 3.496 | 3.006 | 2.925 | 2.768 | 2.870 | 2.986 | 2.882 | 2.859 |
| 1,2,3,4,7,8-Hexa-CDD | 1.847 | 11.21 | 1.477 | 2.216 | 2.203 | 1.984 | 2.244[a] | 2.220 | 2.096 | 1.902 | 2.127 |
| 1,2,3,6,7,8-Hexa-CDD | 1.372 | 19.39 | 1.098 | 1.647 | 1.550 | 1.663[a] | 1.496 | 1.414 | 1.316 | 1.549 | 1.485 |
| 1,2,3,7,8,9-Hexa-CDD | 2.325 | 12.57 | 1.860 | 2.790 | 2.623 | 2.640 | 2.611 | 2.505 | 2.450 | 2.488 | 2.666 |
| 1,2,3,4,6,7,8-Hepta-CDD | 3.036 | 5.61 | 2.429 | 3.644 | 3.016 | 2.996 | 2.972 | 3.048 | 3.007 | 3.022 | 3.094 |
| Octa-CDD | 2.044 | 5.66 | 1.635 | 2.453 | 2.009 | 1.999 | 1.907 | 2.022 | 2.016 | 1.880 | 1.900 |

[a] Outside ±20% RSD from average RRF.

TABLE 6-4. SUMMARY OF BLANK TRAIN DATA

| Sample | Analytes identified | Amount found (ng) |
|---|---|---|
| 13012-13016 proof blank | Total TCDD | 0.027 |
| | Octa-CDD | 0.14 |
| 15012-15016 field blank | Octa-CDD | 0.06 |
| 18012-18016 post blank | Total TCDD | 0.024 |
| | | 0.073 |

### 6.2.1.4 Precision Results for Duplicate Injections--

Duplicate analysis by replicate injection was performed for the controlled location run 1 MM5 sample. Table 6-5 summarizes the results including the average and relative percent difference (RPD). Results are reported in total nanograms per sample with no blank correction. Precision is calculated by taking the difference (range) between the analysis results divided by the average times 100. The computer-generated spreadsheets for these samples are in Appendix L.

Precision for PCDD/PCDF, reported as totals, was 5% (RPD) or less. Precision values reported for specific isomers ranged from less than 1% (RPD) to 12% (RPD) for compounds detected above 0.08 ng and 15% (RPD) to 56% (RPD) for compounds detected below 0.08 ng.

Although no data quality objective was specified for replicate injection precision, results are quite consistent for analytes detected above 0.08 ng per compound.

## 6.2.2 Metals

The QC checks for metals included the analysis of selected samples in duplicate, samples spikes and SRM results, monitoring instrument calibration drift, and the analysis of the blank train samples.

### 6.2.2.1 Duplicate Sample Analyses--

Nine of the metals samples (all from run 1) were selected for duplicate analysis. The results of the duplicate analyses are shown in Table 6-6. Detailed data are in Appendix L. The percent difference for all duplicate analyses were less than 17%, except for the arsenic analysis of the lime slurry which was slightly higher at 33% difference.

### 6.2.2.2 Spiked Sample Analysis and NBS SRM Results--

Two feed samples were selected for spiked sample analysis and NBS SRM 1633a, Trace Elements in Coal Fly Ash, was also analyzed. The results are presented in Table 6-7. Detailed data are in Appendix L.

TABLE 6-5. PRECISION RESULTS FOR DUPLICATE INJECTION OF MM5 SAMPLE

| Analyte | Amount found (ng) | Amount found (ng) | Average (ng) | Precision (RPD)[a] (%) |
|---|---|---|---|---|
| Total tetra-CDF | 3.72 | 3.65 | 3.69 | 2 |
| Total penta-CDF | 2.97 | 3.11 | 3.04 | 5 |
| Total hexa-CDF | 1.71 | 1.75 | 1.73 | 2 |
| Total hepta-CDF | 0.953 | 0.979 | 0.97 | 3 |
| Octa-CDF | 0.251 | 0.259 | 0.26 | 3 |
| Total tetra-CDD | 0.674 | 0.683 | 0.68 | 1 |
| Total penta-CDD | 0.716 | 0.716 | 0.72 | 0 |
| Total hexa-CDD | 1.08 | 1.14 | 1.11 | 5 |
| Total hepta-CDD | 0.963 | 0.968 | 0.97 | 1 |
| Octa-CDD | 1.06 | 1.019 | 1.04 | 4 |
| 2,3,7,8-Tetra-CDF | 0.504 | 0.528 | 0.52 | 5 |
| 1,2,3,4,8-Penta-CDF | 0.0561 | 0.0662 | 0.061 | 17 |
| 1,2,3,7,8-Penta-CDF | 0.225 | 0.252 | 0.24 | 11 |
| 2,3,4,7,8-Penta-CDF | 0.228 | 0.245 | 0.24 | 7 |
| 1,2,3,4,7,8-Hexa-CDF | 0.332 | 0.317 | 0.32 | 5 |
| 1,2,3,6,7,8-Hexa-CDf | 0.171 | 0.176 | 0.17 | 3 |
| 1,2,3,4,7,9-Hexa-CDF | ND[b]<br><0.0511 | ND<br>< 0.0498 | - | - |
| 2,3,4,6,7,8-Hexa-CDF | 0.196 | 0.194 | 0.19 | 1 |
| 1,2,3,7,8,9-Hexa-CDF | 0.0133 | 0.0233 | 0.018 | 56 |
| 1,2,3,4,6,7,8-Hepta-CDF | 0.604 | 0.603 | 0.60 | < 1 |
| 1,2,3,4,7,8,9-Hepta-CDF | 0.111 | 0.124 | 0.12 | 11 |
| Octa-CDF | 0.251 | 0.259 | 0.26 | 3 |
| 2,3,7,8-TCDD | 0.0465 | 0.0464 | 0.046 | < 1 |
| 1,2,3,7,8-Penta-CDD | 0.0725 | 0.0683 | 0.070 | 6 |
| 1,2,3,4,7,8-Hexa-CDD | 0.0690 | 0.0806 | 0.075 | 15 |
| 1,2,3,6,7,8-Hexa-CDD | 0.152 | 0.135 | 0.14 | 12 |
| 1,2,3,7,8,9-Hexa-CDD | 0.119 | 0.129 | 0.12 | 8 |
| 1,2,3,4,6,7,8-Hepta-CDD | 0.510 | 0.508 | 0.51 | < 1 |
| Octa-CDD | 1.056 | 1.02 | 1.04 | 3 |
| GC/MS data file: | 8910A31X4 | | 8910A31X5 | |
| Sample ID: | 1028-1032 (MM5 outlet) | 1028-1032 (MM5 outlet Rep. inj.) | | |
| Analyis date: | 1/31/88 | | 1/31/88 | |

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[a] RPD (relative percent difference) = 100(range ÷ mean).

[b] ND = Not detected.

### TABLE 6-6. DUPLICATE METALS ANALYSIS RESULTS

| Sample | Units | Arsenic final results | Cadmium final results | Chromium final results | Mercury final results | Lead final results |
|---|---|---|---|---|---|---|
| Run 1 | | | | | | |
| Cyclone ash | µg/g | 30.3 | 30.5 | 390 | < 7.96 | 2,168 |
| Dup | µg/g | 34.1 | 30.8 | 377 | < 22.6 | 2,028 |
| % difference | | 12.0 | 1.00 | 3.44 | NA | 6.69 |
| Run 1 | | | | | | |
| Lime slurry | µg/g | 4.95 | < 0.229 | < 0.955 | < 0.225 | < 5.85 |
| Dup | µg/g | 3.55 | < 0.224 | < 0.931 | < 0.223 | < 5.70 |
| % difference | | 33.1 | NA | NA | NA | NA |
| Run 1 | | | | | | |
| Inlet acetone rinse | µg total | 94.5 | 121 | 458 | 205 | 3,943 |
| Dup | µg total | 94.5 | 122 | 469 | 203 | 3,961 |
| % difference | | 0.00 | 0.46 | 2.45 | 1.03 | 0.45 |
| Run 1 | | | | | | |
| Outlet acetone rinse | µg total | < 2.58 | < 0.750 | 4.29 | < 3.16 | 15.4 |
| Dup | µg total | < 2.58 | < 0.750 | 3.69 | < 3.19 | 15.9 |
| % difference | | NA | NA | 15.0 | NA | 2.94 |
| Run | | | | | | |
| Inlet front half | µg total | 799 | 1,770 | 3,824 | 726 | 44,417 |
| Dup | µg total | 751 | 1,716 | 3,897 | 681 | 44,472 |
| % difference | | 6.29 | 3.12 | 1.89 | 6.29 | 0.12 |
| Run 1 | | | | | | |
| Outlet front half | µg total | < 9.03 | 12.7 | < 4.47 | < 9.55 | 204 |
| Dup | µg total | < 9.03 | 11.7 | < 4.47 | < 10.3 | 203 |
| % difference | | NA | 8.37 | NA | NA | 0.57 |
| Run 1 | | | | | | |
| Inlet back half | µg total | 1.52 | 4.27 | 2.04 | NA | 14.7 |
| Dup | µg total | NA | 4.20 | 1.72 | NA | 14.8 |
| % difference | | NA | 1.69 | 16.93 | NA | 0.47 |
| Run 1 | | | | | | |
| Inlet permanganate | µg/g | NA | NA | NA | 0.00121 | NA |
| Dup | µg/g | NA | NA | NA | 0.00134 | NA |
| % difference | | NA | NA | NA | 10.13 | NA |
| Run 1 | | | | | | |
| Outlet permanganate | µg/g | NA | NA | NA | 0.000769 | NA |
| Dup | µg/g | NA | NA | NA | 0.000758 | NA |
| % difference | | NA | NA | NA | 1.37 | NA |

NA = not applicable or not analyzed.

## TABLE 6-7. ASH AND LIME SLURRY METALS SPIKE AND RECOVERY DATA

| | Metal | | | | |
|---|---|---|---|---|---|
| | Arsenic | Cadmium | Chromium | Mercury | Lead |
| Baghouse ash (µg/g) | 47.6 | 129 | 152 | 80.2 | 2,767 |
| With spike (µg/g) | 134 | 227 | 185 | 244 | 6,011 |
| Spike level (µg/g) | 98.6 | 98.6 | 98.6 | 197 | 3,254 |
| Recovery (%) | 88.0 | 99.4 | 33.4 | 82.9 | 99.7 |
| Lime slurry (µg/g) | 4.95 | a | a | a | a |
| | 3.55 | a | a | a | a |
| With spike (µg/g) | 16.1 | 8.98 | 5.97 | 19.0 | 19.8 |
| Spike level (µg/g) | 9.48 | 9.48 | 9.48 | 19.0 | 28.4 |
| Recovery (%) | 125 | 94.8 | 63.0 | 100 | 69.5 |
| NBS SRM 1633a (µg/g) | 127 | a | 223 | a | 124 |
| Certified value (µg/g) | 145 | 1.00 | 196 | 0.16 | 72.4 |
| Recovery (%) | 87.5 | NA[b] | 114 | NA | 172 |
| Low reference spike (µg total) | 5.83 | 5.07 | 4.61 | 9.60 | 17.0 |
| Spike level (µg total) | 4.90 | 4.90 | 4.90 | 9.80 | 14.7 |
| Recovery (%) | 119 | 104 | 94.0 | 98.0 | 116 |
| High reference spike (µg total) | 59.1 | 52.4 | 54.5 | 97.3 | 1,836 |
| Spike level (µg total) | 50.0 | 50.0 | 50.0 | 100 | 1,650 |
| Recovery (%) | 118 | 105 | 109 | 97.3 | 111 |

a = Below detection limits.

b = NA - Not applicable.

6.2.2.3 Instrument Calibrations--

Calibrations for the three analyzers are summarized in Table 6-8. Detailed data are in Appendix L. All calibration checks met the requirements given in the project QA Plan.

6.2.2.4 Blank Train Analyses--

The blank train sample analyses are shown in Table 6-9. The posttest blank showed that some sample carryover occurred. Mercury was the only element consistently measured in the blanks. A blank correction of 8 µg was applied for mercury. Detailed data are in Appendix L.

### 6.2.3 Sampling Equipment

A summary of equipment calibration results is presented in Table 6-10. Acceptable ranges for the calibrations are included. All of the equipment fell within acceptable limits.

Isokinetic performance and leak check results are presented for semivolatile data (Table 6-11) and particulate/metals data (Table 6-12). All of the test data fell within isokinetic limits of 100 ± 10%. Leak checks were acceptable in all cases except one. The final leak check, the run 3 inlet semivolatiles train, showed such a high leak rate that no vacuum could be drawn. It is believed that this large leak was caused when the probe nozzle was severely jarred upon being removed from the stack. No indications of a leak of such magnitude were observed during test operations.

### 6.2.4 Continuous Emission Monitoring

The QA/QC checks for the MRI CEMs included daily leak checks, zero, and span drift measurements, and comparison of the working standards against EPA protocol no. 1 gas cylinders.

6.2.4.1 Leak Checks--

The MRI gas analyzers were operated as three separate CEM systems. Leak checks of each of the three monitoring systems were done before and after every run. The leak checks consisted of sealing the sampling probe, producing a vacuum equal to the highest observed vacuum on the system between the probe and the sampling pump, sealing off the pump, and checking for a leakage rate of < 4% of normal flow. All leak checks were completed successfully. Leak check results are noted on the data logger printouts shown in Appendix F.

6.2.4.2 Calibration Drift--

The working standards are shown in Table 6-13. The span gases were certified to at least ±2% by the manufacturers. Each analyzer was calibrated twice daily with zero and span gases. Table 6-14 shows the daily zero drift, and Table 6-15 shows the daily span drift for each analyzer. Only the $SO_2$ analyzer used at the inlet failed to meet the unofficial daily drift criterion of < 10%. A careful review of the data indicated that the span drift was sudden rather than gradual, that it usually occurred during a port change, and it was clearly identifiable by a sudden drop in the measured concentration. The probable cause was poisoning of the electrochemical sensor. Therefore, only data before the first sensitivity loss were reported, and only the initial calibration values were used in calculating concentrations for this analyzer.

TABLE 6-8. METALS INSTRUMENT CHECK STANDARD DATA AND PERCENT DRIFT CALCULATIONS

| ICAP run | Element Cd | % drift | Element Cr | % drift | Element Hg | % drift | Element Pb | % drift |
|---|---|---|---|---|---|---|---|---|
| 3/23/88 | | | | | | | | |
| Initial ICS | 5.1069 | | 5.0202 | | 5.102 | | 5.1591 | |
| ICS1 | 5.106 | 0.02 | 4.9996 | 0.41 | 5.1285 | 0.52 | 5.1897 | 0.59 |
| ICS2 | 5.1484 | 0.81 | 5.0565 | 0.72 | 5.3784 | 5.42 | 5.3095 | 2.92 |
| ICS3 | 5.1555 | 0.95 | 5.0662 | 0.92 | 5.3894 | 5.63 | 5.3963 | 4.60 |
| 3/23/88 | | | | | | | | |
| Initial ICS | 5.1287 | | 5.0635 | | 5.1273 | | 5.0773 | |
| ICS1 | 5.2551 | 2.46 | 5.2280 | 3.25 | 5.3269 | 3.89 | 5.2546 | 3.49 |
| ICS2 | 5.3029 | 3.340 | 5.2559 | 3.80 | 5.4021 | 5.36 | 5.2510 | 3.42 |
| ICS3 | 5.3222 | 3.77 | 5.2256 | 3.20 | 5.4371 | 6.04 | 5.2624 | 3.65 |
| 4/12/88 | | | | | | | | |
| Initial ICS | 5.0635 | | 50.424 | | 5.0489 | | 5.0269 | |
| ICS1 | 5.0869 | 0.46 | 5.0437 | 0.03 | 5.0892 | 0.80 | 5.0338 | 0.14 |
| ICS2 | 5.1201 | 1.12 | 5.1225 | 1.59 | 5.0146 | 0.68 | 5.0811 | 1.08 |
| 6/7/88 | | | | | | | | |
| Initial ICS | 5.0223 | | 5.0368 | | NA | | 5.0824 | |
| ICS1 | 4.9558 | 1.32 | 4.9838 | 1.05 | NA | NA | 5.2699 | 3.69 |
| ICS2 | 5.0530 | 0.61 | 5.0637 | 0.53 | NA | NA | 5.4326 | 6.89 |

| GFAA run | Absorbance | % drift | Hg CVAAS run | Absorbance | % drift |
|---|---|---|---|---|---|
| 3/31/88 Pb | | | 1/7/88 | | |
| Initial ICS | 0.119 | | Initial ICS | 0.144 | |
| ICS1 | 0.119 | 0.00 | ICS1 | 0.142 | 1.39 |
| ICS2 | 0.120 | 0.84 | ICS2 | 0.141 | 2.08 |
| ICS3 | 0.121 | 1.68 | ICS3 | 0.144 | 0.00 |
| ICS4 | 0.123 | 3.36 | ICS4 | 0.144 | 0.00 |
| 4/1/88 As | | | 4/9/88 | | |
| Initial ICS | 0.197 | | Iniital ICS | 0.244 | |
| ICS1 | 0.208 | 5.58 | ICS1 | 0.262 | 7.38 |
| ICS2 | 0.215 | 9.14 | ICS2 | 0.269 | 10.25 |
| ICS3 | 0.205 | 4.06 | | | |
| ICS4 | 0.211 | 7.11 | 4/13/88 | | |
| ICS5 | 0.212 | 7.61 | | | |
| | | | Iniital ICS | 0.236 | |
| 4/4/88 As | | | ICS1 | 0.236 | 0.00 |
| | | | ICS2 | 0.239 | 1.27 |
| Initial ICS | 0.211 | | | | |
| ICS1 | 0.214 | 1.42 | 4/14/88 | | |
| ICS2 | 0.231 | 9.48 | | | |
| ICS3 | 0.233 | 10.43 | Initial ICS | 0.223 | |
| ICS4 | 0.235 | 11.37 | ICS1 | 0.226 | 1.35 |
| ICS5 | 0.225 | 6.64 | ICS2 | 0.228 | 2.24 |
| ICS6 | 0.234 | 10.90 | | | |

(Continued)

TABLE 6-8 (Concluded)

| GFAA run | Absorbance | % drift | Hg CVAAS run | Absorbance | % drift |
|---|---|---|---|---|---|
| **4/8/88 Pb** | | | **6/7/88** | | |
| Initial ICS | 0.147 | | Initial ICS | 0.256 | |
| ICS1 | 0.135 | 8.16 | ICS1 | 0.256 | 0.00 |
| ICS2 | 0.125 | 14.97 | ICS2 | 0.271 | 5.86 |
| | | | ICS3 | 0.273 | 6.64 |
| **6/6/88 As** | | | | | |
| Initial ICS | 0.199 | | | | |
| ICS1 | 0.204 | 2.51 | | | |
| ICS2 | 0.215 | 8.04 | | | |
| ICS3 | 0.227 | 14.07 | | | |
| **6/6/88 Pb** | | | | | |
| Initial ICS | 0.229 | | | | |
| ICS1 | 0.231 | 0.87 | | | |
| ICS2 | 0.232 | 1.31 | | | |

Note: These analyses were conducted on a Jarrell-Ash Model 1155A ICP-AES, a Perkin-Elmer Model 5000 Zeeman atomic absorption spectrometer and a Perkin-Elmer 3030B atomic absorption spectrometer. The atomic abosrption units were equipped with a hollow cathode lamp for Pb or electrodeless discharge lamps for Hg or As.

## TABLE 6-9. METALS BLANK TRAIN ANALYSES

|  | As (µg) | Cd (µg) | Cr (µg) | Pb (µg) | Hg (µg) |
|---|---|---|---|---|---|
| Proof blank |  |  |  |  |  |
| Acetone rinse | < 1.29[a] | < 0.375 | < 0.638 | 0.79 | < 1.52 |
| Front half | < 3.87 | 1.14 | < 1.91 | 1.68 | 5.76 |
| Back half | < 0.14 | 0.439 | < 1.11 | 0.671 | 0.0063 |
| Permanganate |  |  |  |  | < 0.00049 |
| Total | < 5.3[b] | < 2.0[b] | < 3.7[b] | 3.1 | 5.8 |
| Stack blank |  |  |  |  |  |
| Acetone rinse | < 1.29 | < 0.375 | < 0.638 | < 0.44 | < 1.55 |
| Front half | < 7.74 | < 2.25 | < 3.83 | < 2.64 | 9.23 |
| Back half | < 0.141 | 0.329 | < 1.12 | 3.82 | < 0.0052 |
| Permanganate |  |  |  |  | < 0.00049 |
| Total | < 9.2[b] | < 3.0[b] | < 5.6[b] | < 6.9[b] | 10.8[b] |
| Posttest blank |  |  |  |  |  |
| Acetone rinse | < 1.29 | < 0.375 | < 0.638 | 2.64 | 1.78 |
| Front half | < 6.45 | 3.42 | < 3.19 | 17.8 | 8.64 |
| Back half | < 0.143 | < 0.399 | < 1.13 | 4.32 | < 0.0066 |
| Permanganate |  |  |  |  | < 0.0005 |
| Total | < 7.9[b] | < 4.2[b] | < 5.0[b] | 24.8 | 10.4 |

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[a] The metal values shown to right of < denote detection limit of the analysis.

[b] Totals include detection limit.

TABLE 6-10. CALIBRATION RESULTS FOR SAMPLING EQUIPMENT

| Parameter | Acceptance limit | Pass/fail |
|---|---|---|
| Probe nozzle | 3 measurements within 0.1 mm | All pass |
| Gas meter volume[a] (Y-factor) | Post-test ±5% of pretest | All pass |
| Gas meter temperature | ±5°F | All pass |
| Stack temperature sensor | ±1.5% | All pass |
| Final impinger temperature sensor | ±5°F | All pass |
| Filter temperature sensor | ±5°F | All pass |
| Aneroid barometer | ±2.5 mm Hg | Pass |
| S-type pitot tube | Method 2 criteria | All pass |

[a] Actual values as follows:

|  | Pretest | Posttest |
|---|---|---|
| Console 10 | 1.127 | 1.1381 |
| Console 3 | 1.0158 | 1.0182 |
| Console 9 | 1.0229 | 1.0153 |
| Console 6 | 0.9870 | 0.9813 |

### TABLE 6-11. SEMIVOLATILES TESTING ISOKINETICS[a] AND LEAK CHECK[b] SUMMARY

| Date | Run No. | % isokinetic | Leak check | Sampling port | Leak rate | | Pressure | |
|---|---|---|---|---|---|---|---|---|
| | | | | | $cm^3/min$ | $(ft^3/min)$ | mm $H_2O$ | (in. $H_2O$) |
| 12/9/87 | 1-Inlet | 99.2 | Initial | 2 | 84.9 | (0.003) | 381 | (15) |
| | | | Port change | 2 | 28.3 | (0.001) | 127 | (5) |
| | | | Continue | 3 | 141 | (0.005) | 381 | (15) |
| | | | Final | 3 | 28.3 | (0.001) | 178 | (7) |
| | 1-Outlet | 100.1 | Initial | 2 | 340 | (0.012) | 381 | (15) |
| | | | Port change | 2 | 141 | (0.005) | 457 | (18) |
| | | | Continue | 3 | 141 | (0.005) | 381 | (15) |
| | | | Final | 3 | 28.3 | (0.001) | 457 | (18) |
| 12/10/87 | 2-Inlet | 99.4 | Initial | 2 | 226 | (0.008) | 381 | (15) |
| | | | Port change | 2 | 113 | (0.004) | 152 | (6) |
| | | | Continue | 3 | 84.9 | (0.003) | 381 | (15) |
| | | | Port change | 3 | 28.3 | (0.001) | 178 | (7) |
| | | | Continue | 1 | 141 | (0.005) | 381 | (15) |
| | | | Final | 1 | 56.6 | (0.002) | 228 | (9) |
| | 2-Outlet | 100.3 | Initial | 2 | 84.9 | (0.003) | 431 | (17) |
| | | | Replace XAD | 2 | 84.9 | (0.003) | 609 | (24) |
| | | | Continue | 3 | 84.9 | (0.003) | 381 | (15) |
| | | | Port change | 2 | 141 | (0.005) | 381 | (15) |
| | | | Continue | 2 | 84.9 | (0.003) | 533 | (21) |
| | | | Port change | 3 | 84.9 | (0.003) | 508 | (20) |
| | | | Continue | 1 | 84.9 | (0.003) | 381 | (15) |
| | | | Final | 1 | 28.3 | (0.001) | 533 | (21) |
| 12/12/87 | 3-Inlet | 100.9 | Initial | 2 | 141 | (0.005) | 381 | (15) |
| | | | Port change | 2 | 170 | (0.006) | 127 | (5) |
| | | | Continue | 3 | 198 | (0.007) | 381 | (15) |
| | | | Port change | 3 | 28.3 | (0.001) | 152 | (6) |
| | | | Continue | 1 | 84.9 | (0.003) | 381 | (15) |
| | | | Final | 1 | 141 | (0.005) | 178 | (7) |
| | 3-Outlet | 104.8 | Initial | 2 | 28.3 | (0.001) | 381 | (15) |
| | | | Port change | 2 | 28.3 | (0.001) | 178 | (7) |
| | | | Continue | 3 | 28.3 | (0.001) | 381 | (15) |
| | | | Port change | 3 | 28.3 | (0.001) | 178 | (7) |
| | | | Continue | 1 | 28.3 | (0.001) | 381 | (15) |
| | | | Final | 1 | | c | | Unattainable |

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[a] The QC objective for isokinetics was 100 ± 10%.

[b] The QC objective for leak checks was a leak-free train or a leakage rate less than or equal to 0.02 cfm, or less than 4% of the average sampling rate (whichever is less).

[c] Nozzle tip severely jarred upon removal from stack. Unable to draw vacuum for final leak check. Sample line believed to be leak free until withdrawl from stack.

TABLE 6-12. PARTICULATE/METALS TESTING ISOKINETICS[a] AND LEAK CHECK[b] SUMMARY

| Date | Run No. | % isokinetic | Leak check | Sampling port | Leak rate | | Pressure | |
|---|---|---|---|---|---|---|---|---|
| | | | | | $cm^3/min$ | ($ft^3/min$) | mm $H_2O$ | (in. $H_2O$) |
| 12/9/87 | 1-Inlet | 99.2 | Initial | 1 | 113 | (0.004) | 381 | (15) |
| | | | Port change | 1 | 56.6 | (0.002) | 152 | (6) |
| | | | Continue | 2 | 84.9 | (0.003) | 381 | (15) |
| | | | Final | 2 | 84.9 | (0.003) | 178 | (7) |
| | 1-Outlet | 106.1 | Initial | 1 | 56.6 | (0.002) | 381 | (15) |
| | | | Port change | 1 | 0.000 | (0.000) | 381 | (15) |
| | | | Continue | 2 | 84.9 | (0.003) | 381 | (15) |
| | | | Final | 2 | 28.3 | (0.001) | 381 | (15) |
| 12/10/87 | 2-Inlet | 100.1 | Initial | 1 | 170 | (0.006) | 381 | (15) |
| | | | Port change | 1 | 56.6 | (0.002) | 101 | (4) |
| | | | Continue | 2 | 170 | (0.006) | 381 | (15) |
| | | | Port change | 2 | 56.6 | (0.002) | 127 | (5) |
| | | | Continue | 3 | 141 | (0.005) | 381 | (15) |
| | | | Final | 3 | 56.6 | (0.002) | 152 | (6) |
| | 2-Outlet | 105.8 | Initial | 1 | 113 | (0.004) | 381 | (15) |
| | | | Port change | 1 | 28.3 | (0.001) | 127 | (5) |
| | | | Continue | 2 | 84.9 | (0.003) | 381 | (15) |
| | | | Port change | 2 | 0.000 | (0.000) | 152 | (6) |
| | | | Continue | 3 | 113 | (0.004) | 381 | (15) |
| | | | Final | 3 | 28.3 | (0.001) | 127 | (5) |
| 12/12/87 | 3-Inlet | 101.7 | Initial | 1 | 84.9 | (0.003) | 381 | (15) |
| | | | Port change | 1 | 56.6 | (0.002) | 152 | (6) |
| | | | Continue | 2 | 84.9 | (0.003) | 381 | (15) |
| | | | Port change | 2 | 56.6 | (0.002) | 178 | (7) |
| | | | Continue | 3 | 84.9 | (0.003) | 381 | (15) |
| | | | Final | 3 | 56.6 | (0.002) | 178 | (7) |
| | 3-Outlet | 104.7 | Initial | 1 | 170 | (0.006) | 381 | (15) |
| | | | Port change | 1 | 28.3 | (0.001) | 127 | (5) |
| | | | Continue | 2 | 198 | (0.007) | 381 | (15) |
| | | | Port change | 2 | 28.3 | (0.001) | 152 | (6) |
| | | | Continue | 3 | 113 | (0.004) | 381 | (15) |
| | | | Final | 3 | 198 | (0.007) | 152 | (6) |

[a] The QC objective for isokinetics was 100 ± 10%.

[b] The QC objective for leak checks was a leak-free train or a leakage rate less than or equal to 0.02 cfm, or less than 4% of the average sampling rate (whichever is less).

## TABLE 6-13. CALIBRATION GASES

| | Gas mixture | Supplier | Grade | Analyzer |
|---|---|---|---|---|
| Zero gases | Nitrogen | Airco | Prepurified | All but THC |
| | Air[a] | Matheson | Zero | THC |
| Span gases | | | | |
| | 106.1 ppm NO in nitrogen | Scott | 1%, protocol 1 | $NO_x$ |
| | 93.1 ppm $SO_2$ in nitrogen | Matheson | 2% | $SO_2$ |
| | 413 ppm $SO_2$ in nitrogen | Scott | 1%, protocol 1 | $SO_2$ |
| | 10.2 ppm propane in HCl air | Scott | 2% | THC |
| | 14.01% oxygen, 12.00% $CO_2$, 296 ppm CO in nitrogen | Scott | 2% | $CO_2$, CO (R1+R2)[b] |
| | 12.09% oxygen, 12.00% $CO_2$, 2,924 ppm CO | Scott | 2% | $O_2$, $CO_2$ (R3)[b]<br>CO |
| | 14.01% $O_2$ in nitrogen | Scott | 1%, protocol 1 | $O_2$ (R1+R2)[b] |

[a] System is purged with zero air, calibration gas flow is then turned off for zero reading. This zero point agrees with the zero measured from ultra high purity gases.

[b] R1+R2 = calibration during run 1 and run 2.
R3 = calibration during run 3.

## TABLE 6-14. DAILY ZERO DRIFT IN CEMS

| | Run 1 | | | Run 2 | | | Run 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Initial | Final | % drift | Initial | Final | % drift | Initial | Final | % drift |
| **Oxygen:** | | | | | | | | | |
| Dryer inlet | 2.79 | 0.0 | 4.9 | 1.99 | 2.51 | 0.8 | 1.64 | 1.95 | 0.7 |
| Dryer outlet | 0.42 | 0.59 | 0.3 | 0.58 | 0.31 | 0.6 | 0.64 | 0.53 | 0.2 |
| Baghouse outlet | 0.40 | 0.32 | 0.1 | 0.28 | 0.22 | 0.1 | 0.92 | 0.32 | 1.3 |
| **Carbon dioxide:** | | | | | | | | | |
| Dryer inlet | 1.63 | 1.53 | 0.2 | 1.93 | 1.92 | 0.0 | 1.97 | 1.86 | 0.2 |
| Dryer outlet | 1.21 | 1.70 | 0.7 | 1.60 | 1.64 | 0.1 | 1.14 | 1.60 | 0.7 |
| Baghouse outlet | 1.09 | 1.58 | 0.7 | 0.91 | 1.56 | 0.8 | 0.98 | 1.08 | 0.2 |
| **Carbon monoxide:** | | | | | | | | | |
| Dryer inlet | 2.30 | 0.28 | 4.0 | 2.30 | 2.11 | 0.4 | 2.54 | 1.35 | 2.4 |
| **Total hydrocarbons:** | | | | | | | | | |
| Dryer inlet | - | - | - | - | - | - | 10.29 | 11.14 | 1.0 |
| **Sulfur dioxide:** | | | | | | | | | |
| Dryer inlet | 3.10 | 3.71 | 1.1 | 4.35 | 5.29 | 3.1 | 8.10 | 8.37 | 0.5 |
| Baghouse outlet | 2.46 | 2.38 | 0.1 | 2.68 | 2.57 | 0.2 | 2.44 | 2.31 | 0.2 |
| **Nitrogen oxides:** | | | | | | | | | |
| Baghouse outlet | 1.53 | 1.15 | 0.8 | 1.61 | 1.27 | 0.7 | 1.94 | 1.20 | 1.6 |

TABLE 6-15. DAILY SPAN DRIFT IN CEMS

| | Run 1 | | | | Run 2 | | | | Run 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Initial | Final | % drift | Span conc. | Initial | Final | % drift | Span conc. | Initial | Final | % drift | Span conc. |
| **Oxygen:** | | | | | | | | | | | | |
| Dryer inlet | 58.79 | 57.52 | 2.7 | 14.0 | 59.21 | 59.23 | 0.9 | 14.0 | 51.05 | 50.82 | 1.1 | 12.1 |
| Dryer outlet | 54.79 | 54.48 | 0.9 | 14.0 | 55.31 | 54.11 | 1.7 | 14.0 | 48.27 | 46.63 | 3.3 | 12.1 |
| Baghouse outlet | 54.91 | 52.49 | 4.4 | 14.0 | 54.70 | 52.02 | 4.9 | 14.0 | 46.08 | 40.72 | 11.2 | 12.1 |
| **Carbon dioxide:** | | | | | | | | | | | | |
| Dryer inlet | 82.05 | 80.99 | 1.2 | 12.0 | 81.63 | 81.73 | 0.1 | 12.0 | 80.87 | 80.68 | 0.1 | 12.0 |
| Dryer outlet | 77.92 | 77.93 | 0.6 | 12.0 | 77.85 | 77.95 | 0.1 | 12.0 | 77.74 | 77.72 | 0.6 | 12.0 |
| Baghouse outlet | 82.70 | 82.75 | 0.5 | 12.0 | 82.95 | 82.94 | 0.8 | 12.0 | 82.00 | 81.98 | 0.1 | 12.0 |
| **Carbon monoxide:** | | | | | | | | | | | | |
| Dryer inlet | 52.09 | 50.19 | 0.2 | 336 | 51.92 | 48.62 | 6.5 | 336 | 49.90 | 52.55 | 7.8 | 338 |
| **Total hydrocarbon:** | | | | | | | | | | | | |
| Dryer inlet | - | - | - | - | - | - | - | - | 86.71 | 100.61 | 15.8 | 10.2 |
| **Sulfur dioxide:** | | | | | | | | | | | | |
| Dryer inlet | 68.90 | 46.83[a] | 41.6 | 413 | 50.10 | 21.35[a] | 96.1 | 413 | 86.75 | 24.33[a] | 132.5 | 413 |
| Baghouse outlet | 86.32 | 82.54 | 4.5 | 93.1 | 83.26 | 82.62 | 0.6 | 93.1 | 81.61 | 78.15 | 4.3 | 93.1 |
| **Nitrogen oxides:** | | | | | | | | | | | | |
| Baghouse outlet | 48.25 | 48.90 | 2.2 | 106.1 | 49.44 | 49.57 | 1.0 | 106.1 | 48.55 | 49.04 | 2.6 | 106.1 |

[a] Final $SO_2$ calibration not used to calculate sample concentrations. See text.

#### 6.2.4.3 Calibration Cylinder Check for Continuous Monitoring of Combustion Gases--

Span cylinder accuracy checks were performed for CO, $CO_2$, $SO_2$, $O_2$, and THC. Results are presented in Table 6-16.

Accuracy values ranged from 91% to 106% for all gas measurements, well within the objective of 85% to 115% recovery.

### 6.2.5 Process Samples

Duplicate sample analysis results (performed by Galbraith Laboratories) are presented in Table 6-17. Samples from run 1 were used for duplicate analysis, which followed the same methodology as normal sample analysis. Precision results for the duplicate analyses were all 3% (RPD) or better, except for percent carbon analysis of the cyclone ash and the bottom ash, which varied by 12% (RPD) and 42% (RPD), respectively.

## 6.3 AUDITS

Several independent audits were conducted during this project. These included analysis of performance audit samples, systems audits, and audits for data quality. These independent audits are summarized below.

### 6.3.1 Performance Audit Samples

Performance audit samples (PAS) were prepared by the QAC using standard solutions independent of and separate from project calibration standards. Actual amounts or concentrations of the PAS were not disclosed to the analysts until the results of analysis were reported in writing to the QAC. The QAC calculated accuracy results and reported these to project and department management and to the QAM.

Audit samples for PCDD/PCDF and metals were also provided by EPA and analyzed together with the field samples.

Two types of PCDD/PCDF audit samples were processed along with the MERC samples: (1) spikes and blanks, and (2) instrument performance. Clean XAD and water matrices were spiked by the QAC with known amounts of PCDD/PCDF and extracted by the analyst in the same manner as the samples. Blanks were run to check for contamination of sampling materials. Eight spikes and blanks were extracted and analyzed: (a) XAD, (b) filter, (c) water, and (d) XAD/filter.

The instrument performance sample is a known amount of a spiked solution with method and recovery internal standards added. It is given to the mass spectrometer operator by the QAC. This sample is used to independently verify that the GC/MS is operating properly while the spikes and blanks verify that the extraction procedure is adequate. A summary of the spikes and instrument performance results for this project are listed in Tables 6-18 through 6-21.

## TABLE 6-16. SPAN CYLINDER ACCURACY CHECKS

| Test mixture | Analyzer | Measured value | Accuracy (%) | |
|---|---|---|---|---|
| None | $NO_x$ | No second cylinder available | | |
| 9.5 ppm propane | THC | 9.7 | 102 | NBS 1666b |
| 93.1 ppm $SO_2$ | $SO_2$ inlet | 87.5 | 94 | Standard for outlet |
| 14.01% $O_2$ | $O_2$ inlet | 14.00 | 100 | BAL 936 EPA P 1 |
| | Dryer outlet | 12.75 | 91 | |
| | Baghouse outlet | 14.17 | 101 | |
| 12.4% $CO_2$ | $CO_2$ dryer outlet | 11.9 | 96 | BAL 3172 EPA P 1 |
| | Dryer outlet | 12.06 | 97 | |
| | Baghouse outlet | 12.38 | 100 | |
| 409.7 ppm CO | CO | 434.6 | 106 | BAL 102 EPA P 1 |
| 412.7 ppm $SO_2$ | $SO_2$ dryer outlet | 381 | 92 | BAL 1907 EPA P 1 |
| | Baghouse outlet | 400.8 | 97 | |
| 4.01% $O_2$ | $O_2$ dryer outlet | 3.99 | 99 | Standard used for runs 1 and 2 |
| | Dryer outlet | 3.70 | 92 | |
| | Baghouse outlet | 4.16 | 104 | |
| 12.0% $CO_2$ | $CO_2$ dryer outlet | 12.11 | 101 | |
| | Dryer outlet | 11.99 | 100 | |
| | Baghouse outlet | 11.98 | 100 | |
| 295 ppm CO | CO | 287.4 | 97 | |

Span gases used (same as used for Run 3)

| | |
|---|---|
| $O_2$ | 12.09% $O_2$ |
| $CO_2$ | 12.00% $CO_2$ |
| CO | 297.4 ppm CO (338 ppm corrected for $CO_2$) |
| THC | 10.2 ppm propane |
| $SO_2$ | 93.1 ppm $SO_2$ at baghouse outlet<br>413 ppm $SO_2$ at dryer inlet |
| $NO_x$ | 106.1 ppm NO |

TABLE 6-17. PRECISION FOR DUPLICATE ANALYSES OF PROCESS SAMPLES[a]

| | % Carbon | % Ash | % CaO | % Solids | Specific gravity |
|---|---|---|---|---|---|
| Fabric filter ash | 5.57<br>5.40<br>$\bar{x}$ = 5.49<br>RPD 3% | 88.96<br>89.26<br>$\bar{x}$ = 89.11<br>RPD 1% | - | - | - |
| Cyclone ash | 1.12<br>0.99<br>$\bar{x}$ = 1.06<br>RPD 12% | 98.30<br>98.38<br>$\bar{x}$ = 98.34<br>RPD 0.1% | - | - | - |
| Bottom ash | 1.58<br>1.03<br>$\bar{x}$ = 1.30<br>RPD 42% | 74.48<br>75.86<br>$\bar{x}$ = 75.17<br>RPD 2% | | | |
| Lime slurry | - | - | 11.76<br>11.91<br>$\bar{x}$ = 11.84<br>RPD 1% | 20.60<br>20.65<br>$\bar{x}$ = 20.63<br>RPD 0.2% | 1.131<br>1.130<br>$\bar{x}$ = 1.13<br>RPD 0.1% |

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a Run 1 samples used for duplicate analysis.

b Precision is expressed as range percent deviation (RPD): $\frac{\text{range}}{\text{mean}} \times 100$ .

TABLE 6-18. DIOXIN/FURAN RESULTS FOR THE INSTRUMENT PERFORMANCE SAMPLE

| Analyte | Found (ng) | Theoretical (ng) | Accuracy (%) |
|---|---|---|---|
| 2,3,7,8-TCDD | 68.7 | 67.8 | 101 |

TABLE 6-19. DIOXIN/FURAN RESULTS FOR BLANK QA PERFORMANCE SAMPLES[a]

| Sample | Analytes detected | Amount (ng) |
|---|---|---|
| XAD (04512) | Octa-CDD | 0.032 |
| Filter (04517) | none | - |
| XAD and filter (04519) | Octa-CDD | 0.027 |
| Water (04515) | Octa-CDD | 0.010 |

[a] Detection limits for dioxins and furans ranged from 0.002 to 0.04 ng.

## TABLE 6-20. TOTAL DIOXIN/FURAN RESULTS FOR SPIKED QA PERFORMANCE SAMPLES[a]

| Analyte | Spiked XAD (04513) | | | Spiked filter (04516) | | | Spiked XAD + filter (04518) | | | Spiked water (04514) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Found (ng) | Theor. (ng) | Accuracy (%) | Found (ng) | Theor. (ng) | Accuracy (%) | Found (ng) | Theor. (ng) | Accuracy (%) | Found (ng) | Theor. (ng) | Accuracy (%) |
| Total tetra-CDF | 1.043 | 1.0 | 104 | 0.391 | 0.40 | 98 | 0.362 | 0.40 | 91 | 0.362 | 0.40 | 91 |
| Total penta-CDF | 1.959 | 2.0 | 98 | 0.74 | 0.80 | 93 | 0.663 | 0.80 | 83 | 0.655 | 0.80 | 82 |
| Total hexa-CDF | 9.420 | 10.0 | 94 | 3.98 | 4.0 | 100 | 3.287 | 4.0 | 82 | 3.069 | 4.0 | 77 |
| Total hepta-CDF | 5.0071 | 5.0 | 100 | 1.83 | 2.0 | 92 | 1.676 | 2.0 | 84 | 1.435 | 2.0 | 72 |
| Octa-CDF | 4.554 | 5.0 | 91 | 1.53 | 2.0 | 77 | 1.688 | 2.0 | 84 | 1.901 | 2.0 | 95 |
| Total tetra-CDD | 0.9790 | 1.0 | 98 | 0.361 | 0.40 | 90 | 0.377 | 0.46 | 94 | 0.365 | 0.40 | 91 |
| Total penta-CDD | 0.965 | 1.0 | 97 | 0.352 | 0.40 | 88 | 0.344 | 0.46 | 86 | 0.347 | 0.40 | 87 |
| Total hexa-CDD | 7.016 | 7.5 | 94 | 2.66 | 3.0 | 89 | 2.507 | 3.0 | 84 | 2.104 | 3.0 | 70 |
| Total hepta-CDD | 2.010 | 2.5 | 80 | 0.740 | 1.0 | 74 | 0.754 | 1.0 | 75 | 0.705 | 1.0 | 71 |
| Octa-CDD | 4.694 | 5.0 | 94 | 1.69 | 2.0 | 85 | 1.735 | 2.0 | 87 | 1.661 | 2.0 | 83 |

[a] All values met the data quality objective for accuracy of 50-150%.

TABLE 6-21. ISOMER SPECIFIC DIOXIN/FURAN RESULTS FOR SPIKED QA PERFORMANCE SAMPLES

| Analyte | Spiked XAD (04513) | | | Spiked filter (04516) | | | Spiked XAD + filter (04518) | | | Spiked water (04514) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Found (ng) | Theor. (ng) | Accuracy (%) | Found (ng) | Theor. (ng) | Accuracy (%) | Found (ng) | Theor. (ng) | Accuracy (%) | Found (ng) | Theor. (ng) | Accuracy (%) |
| 2,3,7,8-Tetra-CDF | 1.0331 | 1.0 | 103 | 0.391 | 0.40 | 98 | 0.363 | 0.40 | 91 | 0.362 | 0.40 | 91 |
| 1,2,3,7,8-Penta-CDF | 1.131 | 1.0 | 113 | 0.430 | 0.40 | 108 | 0.358 | 0.40 | 90 | 0.362 | 0.40 | 91 |
| 2,3,4,7,8-Penta-CDF | 0.938 | 1.0 | 94 | 0.396 | 0.40 | 99 | 0.3503 | 0.40 | 88 | 0.339 | 0.40 | 85 |
| 1,2,3,4,7,8-Hexa-CDF | 2.530 | 2.5 | 101 | 0.929 | 1.0 | 93 | 0.869 | 1.0 | 87 | 0.961 | 1.0 | 96 |
| 1,2,3,6,7,8-Hexa-CDF | 2.159 | 2.5 | 86 | 1.001 | 1.0 | 100 | 0.8097 | 1.0 | 81 | 0.797 | 1.0 | 80 |
| 2,3,4,6,7,8-Hexa-CDF | 2.356 | 2.5 | 94 | 1.024 | 1.0 | 102 | 0.812 | 1.0 | 81 | 0.778 | 1.0 | 78 |
| 1,2,3,7,8,9-Hexa-CDF | 2.174 | 2.5 | 87 | 0.984 | 1.0 | 98 | 0.714 | 1.0 | 71 | 0.425 | 1.0 | 43[a] |
| 1,2,3,4,6,7,8-Hepta-CDF | 2.908 | 2.5 | 116 | 1.120 | 1.0 | 112 | 0.971 | 1.0 | 97 | 0.900 | 1.0 | 90 |
| 1,2,3,4,7,8,9-Hepta-CDF | 2.387 | 2.5 | 95 | 0.803 | 1.0 | 80 | 0.801 | 1.0 | 80 | 0.608 | 1.0 | 61 |
| Octa-CDF | 4.554 | 5.0 | 91 | 1.53 | 2.0 | 77 | 1.701 | 2.0 | 85 | 1.901 | 2.0 | 95 |
| 2,3,7,8-TCDD | 0.979 | 1.0 | 98 | 0.361 | 0.40 | 90 | 0.377 | 0.40 | 94 | 0.364 | 0.40 | 91 |
| 1,2,3,7,8-Penta-CDD | 0.965 | 1.0 | 97 | 0.352 | 0.40 | 88 | 0.344 | 0.40 | 86 | 0.347 | 0.40 | 87 |
| 1,2,3,4,7,8-Hexa-CDD | 3.276 | 2.5 | 131 | 1.088 | 1.0 | 109 | 0.972 | 1.0 | 97 | 1.073 | 1.0 | 107 |
| 1,2,3,6,7,8-Hexa-CDD | 3.368 | 2.5 | 135 | 1.37 | 1.0 | 137 | 1.464 | 1.0 | 146 | 1.163 | 1.0 | 116 |
| 1,2,3,7,8,9-Hexa-CDD | 2.425 | 2.5 | 97 | 0.988 | 1.0 | 99 | 0.8705 | 1.0 | 87 | 0.565 | 1.0 | 57 |
| 1,2,3,4,6,7,8-Hepta-CDD | 2.010 | 2.5 | 80 | 0.723 | 1.0 | 72 | 0.754 | 1.0 | 75 | 0.705 | 1.0 | 71 |
| Octa-CDD | 4.694 | 5.0 | 94 | 1.69 | 2.0 | 85 | 1.735 | 2.0 | 87 | 1.661 | 2.0 | 83 |

[a] This value did not meet the data quality objective for accuracy of 50-150%.

All but one of the target analytes were within the data quality objective of 50% to 150% accuracy. Therefore, the overall completeness of the accuracy determinations was essentially 100%.

### 6.3.2 EPA Audit Samples

#### 6.3.2.1 PCDD/PCDF Audit Samples--

Three samples were submitted by EPA as XAD resin in wide-mouth jars. The entire contents of each sample were extracted and analyzed for PCDD/PCDF. Results of the analyses and summaries of EPA evaluations are shown in Table 6-22. The EPA results are provided in Table 6-23. The complete EPA report of the audit results and calculations is included in Appendix L.

#### 6.3.2.2 Metals Audit Samples--

Four audit samples for metals were supplied by EPA. The analysis results of these samples are shown in Table 6-24. Only sample 102 for chromium and lead showed results beyond the desired 90% to 110% accuracy limits. The lead result improved to within the acceptance limits after realigning the instrument. The chromium result did not change when the standard addition method was used. After further discussion with the QAC, a separate EPA reference sample, WP283, was added as a further check for chromium. Results for the EPA WP283 sample were consistently within criteria, indicating that accuracy of the results are acceptable.

### 6.3.3 Systems Audits

#### 6.3.3.1 Laboratory Systems Audit--

A laboratory systems audit on January 26 and 27, 1988, was performed concurrently by Mr. Joseph Evans and Dr. Shri Kulkarni of Research Triangle Institute, and MRI's project QAC. The technical systems audit consisted of reviews of procedural documents, discussions with laboratory personnel, and inspection of laboratory facilities and equipment maintenance records. In addition, sample handling procedures and custody records were inspected by the auditors to assure sample integrity.

No major problems were identified during this audit. The RTI auditors, inconcurrence with MRI, did make two specific recommendations for documenting actual laboratory practices and to improve QC records. These recommendations were: (1) that MRI's final report reflect that the metals analyses of samples from the MM5 sampling train were digested according to the "Radian Draft Method" and analyzed by the SW-846 Method 6010, and (2) that criteria for QC checks of analytical balances be established. RTI's laboratory audit report is included in Appendix L.

#### 6.3.3.2 Field Technical Systems Audit--

In addition to the technical systems audit of the laboratory performed by RTI, a check list for field sampling and facility operations was also developed by RTI to assist Dr. Brna (AEERL Project Officer) and Mr. Riley (OAQPS Project Officer) in the evaluation of project procedures during sampling activities.

## TABLE 6-22. EPA AUDIT SAMPLES PCDD/PCDF RESULTS (ng/sample)

| Isomer | F-176[a] | F-145 | F-130 |
|---|---|---|---|
| 2,3,7,8-TCDD | 0.008 | 0.849 | 0.547 |
| Other TCDD | 0.008 | 8.71 | 16.4 |
| 1,2,3,7,8-PeCDD | 0.010 | 1.85 | 3.36 |
| Other PeCDD | 0.010 | 15.3 | 27.4 |
| 1,2,3,4,7,8-HxCDD | 0.023 | 3.97 | 4.57 |
| 1,2,3,6,7,8-HxCDD | 0.031 | 3.54 | 6.45 |
| 1,2,3,7,8,9-HxCDD | 0.015 | 4.88 | 8.46 |
| Other HxCDD | 0.009 | 16.5 | 28.0 |
| 1,2,3,4,6,7,8-HpCDD | 0.012 | 13.2 | 21.3 |
| Other HpCDD | 0.012 | 11.3 | 19.3 |
| Octa-CDD | 0.023 | 22.4 | 33.6 |
| 2,3,7,8-TCDF | 0.004 | 4.31 | 6.28 |
| Other TCDF | 0.004 | 20.8 | 34.8 |
| 1,2,3,4,8-PeCDF | 0.009 | 0.789 | 1.30 |
| 1,2,3,7,8-PeCDF | 0.011 | 1.96 | 3.26 |
| 2,3,4,7,8-PeCDF | 0.009 | 2.24 | 3.91 |
| Other PeCDF | 0.009 | 25.0 | 39.6 |
| 1,2,3,4,7,8-HxCDF | 0.005 | 5.83 | 11.0 |
| 1,2,3,6,7,8-HxCDF | 0.005 | 2.39 | 4.48 |
| 1,2,3,4,7,9-HxCDF | 0.007 | 0.212 | 0.446 |
| 2,3,4,6,7,8-HxCDF | 0.007 | 2.34 | 4.6 |
| 1,2,3,7,8,9-HxCDF | 0.008 | 0.123 | 0.281 |
| Other HxCDF | 0.005 | 14.5 | 25.1 |
| 1,2,3,4,6,7,8-HpCDF | 0.008 | 16.5 | 27.8 |
| 1,2,3,4,7,8,9-HpCDF | 0.016 | 1.17 | 1.50 |
| Other HpCDF | 0.009 | 3.83 | 5.10 |
| Octa-CDF | 0.022 | 10.0 | 5.91 |

(continued)

TABLE 6-22 (continued)

| Isomer | F-176[a] | F-145 | F-130 |
|---|---|---|---|
| EPA Evaluation: | | | |
| % of PCDD within 90% confidence level | 100% | 100% | 100% |
| % of PCDF within 90% confidence level | 100% | 86% | 86% |
| Average % error outside the 90% confidence level | 0% | 5.5% | 6.3% |

[a] Analyte not detected; value denotes detection limit.

## TABLE 6-23. EPA AUDIT RESULTS

**Results of performance audit sample No. 130**

Results of PCDD:
0 of the 11 different PCDD are not within the 90% confidence intervals.
0 of the 11 different PCDD are not within 50% of the 90% confidence intervals.

Results of the PCDF:
2 of the 14 different PCDF are not within the 90% confidence intervals.
2 of the 14 different PCDF are not within 50% of the 90% confidence intervals.

Results based on 2,3,7,8-TCDD equivalency factors:
Based on the 2,3,7,8-TCDD toxic equivalency factors, the average percent error outside the 90% confidence limits was 6.3%, with an average bias of +5.5%.

**Results of performance audit sample No. 145**

Results of PCDD:
0 of the 11 different PCDD are not within the 90% confidence intervals.
0 of the 11 different PCDD are not within 50% of the 90% confidence intervals.

Results of the PCDF:
2 of the 14 different PCDF are not within the 90% confidence intervals.
2 of the 14 different PCDF are not within 50% of the 90% confidence intervals.

Results based on 2,3,7,8-TCDD equivalency factors:
Based on the 2,3,7,8-TCDD toxic equivalency factors, the average percent error outside the 90% confidence limits was 5.5%, with an average bias of +5.2%.

**Results of performance audit sample No. 176**

Results of PCDD:
0 of the 11 different PCDD are not within the 90% confidence intervals.
0 of the 11 different PCDD are not within 50% of the 90% confidence intervals.

Results of the PCDF:
0 of the 14 different PCDF are not within the 90% confidence intervals.
0 of the 14 different PCDF are not within 50% of the 90% confidence intervals.

Results based on 2,3,7,8-TCDD equivalency factors:
Based on the 2,3,7,8-TCDD toxic equivalency factors, the average percent error outside the 90% confidence limits was 0.0%, with an average bias of 0.0%.

Note: For those PCDD and PCDF reported as not detected by the Auditee, three times the reported detection limit (in parentheses) was used for the calculations. The identical procedure was used for calculating the confidence intervals.

TABLE 6-24. RESULTS OF EPA AND INTERNAL METALS AUDIT SAMPLE ANALYSIS

| Audit no. | As (µg) | Accuracy (%) | Cd (µg/mL) | Accuracy (%) | Cr (µg) | Accuracy (%) | Pb (µg) | Accuracy (%) |
|---|---|---|---|---|---|---|---|---|
| 101 | 2270 | 91 | NA | NA | 253 | 101 | 999 | 100 |
| 102 | 1120 | 97 | NA | NA | 169 | 135 | 585 | 117 |
| 103 | NA | NA | 494 | 103 | NA | NA | NA | NA |
| 104 | NA | NA | 161 | 101 | NA | NA | NA | NA |
| Reanalysis 3/23/88 | | | | | | | | |
| 102 | NA | NA | NA | NA | 167 | 134 | NA | NA |
| WP 283 1 | NA | NA | NA | NA | 1.34 | 107 | NA | NA |
| Reanalysis 3/28/88 | | | | | | | | |
| 102 | NA | NA | NA | NA | 155 | 124 | NA | NA |
| WP 283 1 | NA | NA | NA | NA | 1.28 | 102 | NA | NA |

NA = Not analyzed or not applicable.

The certified value of the EPA WP 283 conc. 1 standard is 1.25 µg/mL. The audit sample true values are:

| | |
|---|---|
| 101 | 2500 µg As, 250 µg Cr, 1000 µg Pb |
| 102 | 1150 µg As, 125 µg Cr, 500 µg Pb |
| 103 | 480 µg/mL Cd |
| 104 | 160 µg/mL Cd |

Based on the completed audit check list for the field sampling and analysis, the audit rating was "acceptable with recommendations" and a concensus that MRI was following the protocols as stated in the QAPP. In general, all recommendations referred to refinement of investigative studies for future tests. The audit did identify temperature reading mismatches between the ID fan and fabric filter and between the air heater outlet and dry scrubber inlet. RTI's field audit report is included in Appendix L.

### 6.3.4 Data Audit

An audit of data quality was conducted for data generated from the PCDD/PCDF analyses. This audit report and follow-up actions/comments are presented in Appendix L.

Project records included information regarding sample analyses, qualitative observations, laboratory procedures, and calculations, plus evidence of technical review. The data were found to be traceable, and the documentation indicated that sample preparation and analysis were performed in accordance with the test plan, QAP, and referenced methods.

# SECTION 7.0

## REFERENCES

1. U.S. Environmental Protection Agency. Municipal Waste Combustion Study: Emission Data Base for Municipal Waste Combustors. EPA-530/SW87-021b, June 1987.

2. U.S. Environmental Protection Agency. Emission Test Report, HCl Continuous Monitoring for Municipal Waste Combustion Study, Maine Energy Recovery Company, Solid Waste-to-Energy Facility Refuse-Derived Fuel Process, Biddeford, Maine, April 8, 1988 (EMB Report No. 88-MIN-06A).

3. U.S. Environmental Protection Agency. Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-dioxins and Dibenzofurans. EPA-625/3-87/012, Risk Assessment Forum, October 1986.

4. ASME. Analytical Procedures to Assay Stack Effluent Samples and Residual Combustion Products for Polychlorinated Dibenzo-p-dioxins (PCDD) and Polychlorinated Dibenzofurans (PCDF). Draft analytical protocol, September 18, 1984.

5. U.S. Environmental Protection Agency. Test Methods for Evaluating Solid Waste. SW-846, 3rd ed., November 1986.

6. U.S. Environmental Protection Agency. Determination of 2,3,7,8,-TCDD in Soil and Sediment. Region 7, September 1983.

7. U.S. Environmental Protection Agency. Emission Measurement Branch (EMB) Metals Protocol. Draft report, August 1, 1987.

## SECTION 8.0

## CONVERSION FACTORS

| Multiply English units | By | To obtain SI units |
|---|---|---|
| lb/h | $4.536 \times 10^{-1}$ | kg/h |
| gr/dscf | $2.288 \times 10^{9}$ | ng/dscm |
| gr/dscf | $2.288 \times 10^{3}$ | mg/dscm |
| foot | 0.3048 | meter |
| inch | 2.54 | centimeter |
| tons/day | 0.907 | mg/day |
| gallon | 3.785 | liter |
| Btu/h | 1.05488 | MJ/h |
| $ft^3$/min | 28316.8 | $cm^3$/min |
| inches $H_2O$ | 0.0394 | mm $H_2O$ |